NASW-4945

Small Satellite Technology Initiative
(SSTI Lewis Spacecraft Program)

NASA-CR-201891

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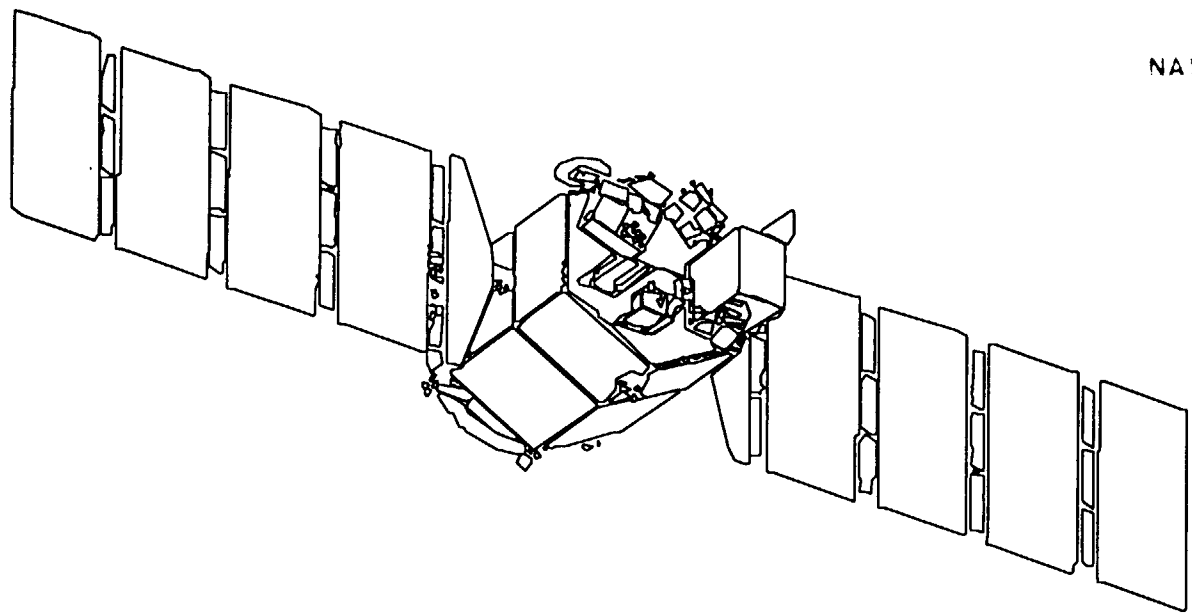
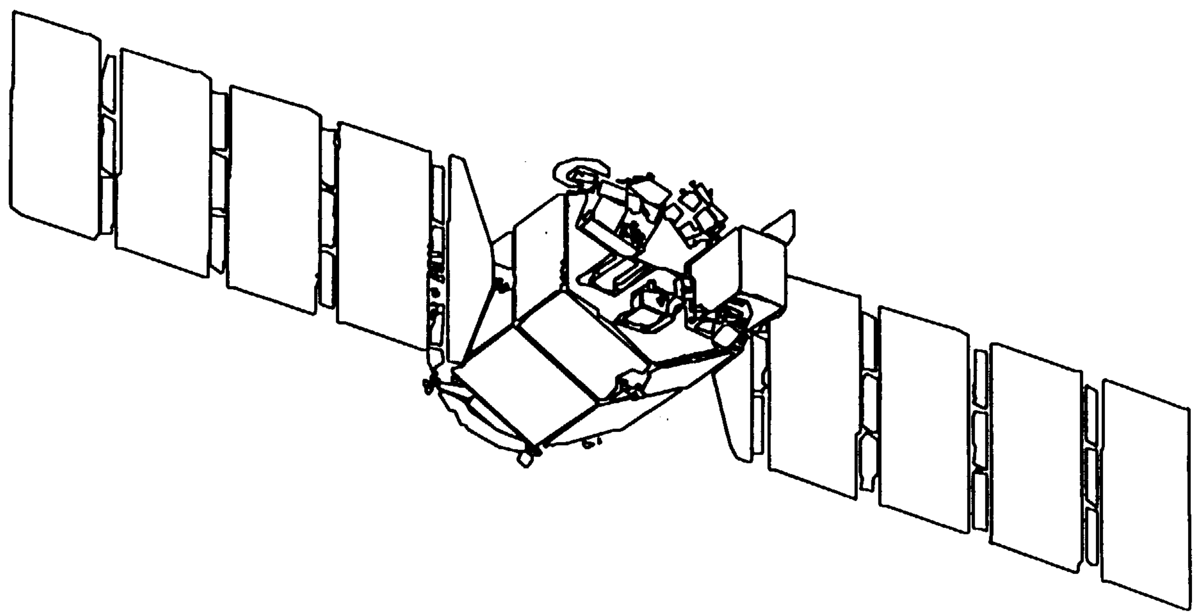


System Critical Design Audit (CDA)

January 17-19, 1995

Book 1 of 3

Small Satellite Technology Initiative
(SSTI Lewis Spacecraft Program)



System Critical Design Audit (CDA)

January 17-19, 1995

Book 1 of 3

SSTI

SSTI-LEWIS CDA AGENDA, DAY 1
TUESDAY, 17 JANUARY 1995

TRW

TIME	TOPIC	PRESENTER
10:00 - 10:10	Welcome & Introduction	Watkins/Sabelhaus
10:10 - 10:20	Program Overview	Marshall
10:20 - 10:50	Technical Overview	Biber/Taylor
	SYSTEM REQUIREMENTS	32
10:50 - 11:10	Performance	Taylor
11:10 - 11:40	Verification	Belte
11:40 - 12:10	Mission Assurance	Niemela
12:10 - 13:00	Lunch	
	SCIENCE & COMMERCIAL APPLICATIONS	
13:00 - 13:15	Overview	Pearlman
13:15 - 13:45	Mission Data Management System	Witcher
13:45 - 14:05	Education	Woods, M.
14:05 - 14:25	Applications Development	Pearlman
14:25 - 14:40	Data Policy	Watkins
	GROUND SEGMENT	
14:40 - 14:50	Overview	Sarina
14:50 - 15:20	Requirements	Berman
15:20 - 15:35	Break	
15:35 - 16:05	CDRS Design	Taylor (Harris)
16:05 - 16:35	SOCC Design	Berman
16:35 - 17:15	Mission Operations	Zion

SSTI-LEWIS CDA AGENDA, DAY 2
WEDNESDAY, 18 JANUARY 1995

TIME			TOPIC	PRESENTER
			SPACECRAFT INTEGRATION, TEST, & LAUNCH	
8:30	-	8:45	Design Summary	Woods, D.
8:45	-	9:30	Mechanical Design Integration	Norden
9:30	-	10:15	Electrical Design Integration	Woods, D.
10:15	-	10:30	Break	
10:30	-	12:00	System Integration & Test	Brooks
12:00	-	12:45	Lunch	
12:45	-	13:30	Launch Interface & Operations	Turner/Desilets
			PAYLOADS & TECHNOLOGY DEMONSTRATIONS	
13:30	-	13:45	Overview	Conte
13:45	-	14:30	HSI	Marmo
14:30	-	15:00	LEISA	Reuter
15:00	-	15:15	Break	
15:15	-	15:45	UCB	Edelstein
15:45	-	16:00	Recorder Interface Module (RIM)	Hayes
16:00	-	16:10	GEM/SLAM	Luers
16:10	-	16:20	Multi-junction GaAs Solar Cells	Slifer
16:20	-	16:30	Amorphous Silicon Solar Cells	Starritt
16:30	-	16:40	ASCE Electronics Design	Larrick
16:40	-	16:55	GPS Attitude Determination	Bauer
16:55	-	17:05	Metal Matrix Heat Strap	Casto
17:05	-	17:15	Micromachined Accelerometers	Conte

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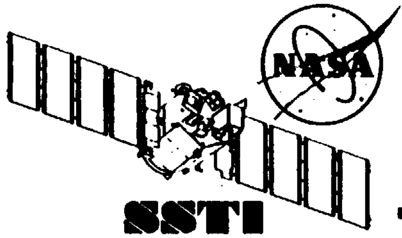
SSTI-LEWIS CDA AGENDA, DAY 3
THURSDAY, 19 JANUARY 1995

TRW

TIME	TOPIC	PRESENTER
	PAYLOADS & TECH DEMOS (CONTINUED)	
8:30 - 8:40	Lossless Data Compression Module	Fong
8:40 - 8:50	Lossy Data Compression	Yeh
8:50 - 9:00	GPC	Shinn
9:00 - 9:15	Cloud and Feature Editing	Davis
9:15 - 9:25	WFOV Star Tracker	Parry
9:25 - 9:35	Mag. Suspended Reaction Wheel	Gerson
9:35 - 9:45	MOCK	Gerson
9:45 - 9:55	Enhanced ACS	Maghami
9:55 - 10:05	On-Orbit ID	Elliott
10:05 - 10:20	PEA/OPA/Cryocoolers	Gerson
10:20 - 10:30	Summary	Conte
10:30 - 10:45	Break	
	SPACECRAFT BUS	
10:45 - 11:00	Overview	Biber
11:00 - 11:30	Structure & Mechanisms	Barrett
11:30 - 11:50	Thermal Control	Biber
11:50 - 12:20	Propulsion	Joseph
12:20 - 13:15	Lunch	
13:15 - 13:45	Electrical Power & Distribution	Starritt
13:45 - 14:15	GN&C	Parry
14:15 - 15:15	Data Management Subsystem	Almeida
15:15 - 15:30	TT&C	Schall
15:30 - 15:45	Break	
15:45 - 16:30	Spacecraft Software	Stafa/Smith
	CLOSURE	
16:30 - 16:50	Program Milestone Summary	Lane
16:50 - 17:00	Closing Remarks	Watkins/Sabelhaus

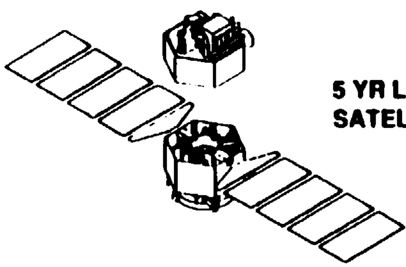
Program Overview

D. Marshall



TRW SSTI Mission Overview

OVER 25 SPACECRAFT AND PAYLOAD TECHNOLOGIES DEMONSTRATED



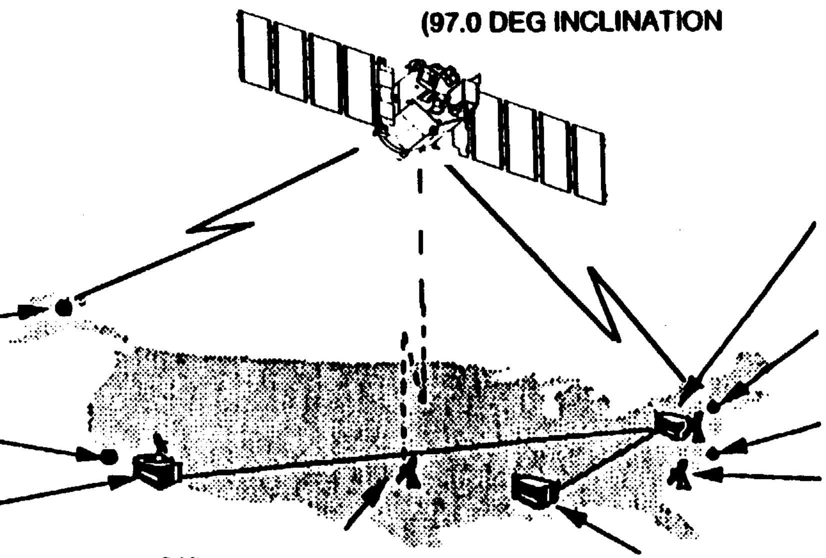
5 YR LLV
SATELLITE

MATURE ADVANCED TECHNOLOGIES INTEGRATED INTO SPACECRAFT BUS

SEPARATE PAYLOAD AND TECHNOLOGY DEMONSTRATION MODULE

SSTI INSTRUMENTS:
- HYPERSPECTRAL IMAGER (HSI)
  - 384 SPECTRAL CHANNELS, 0.4 TO 2.5 μm
  - RADIOMETRIC ACCURACY: 6% HYPERSPECTRAL, 16% PAN
  - GROUND SAMPLE DISTANCE: 5M PANCHROMATIC, 30M HYPERSPECTRAL
- LINEAR ETALON IMAGING SPECTRAL ARRAY (PLANETARY TECHNOLOGY)
- ULTRAVIOLET COSMIC BACKGROUND

523 KM CIRCULAR
SUN-SYNCHRONOUS ORBIT
(97.0 DEG INCLINATION



UNIV OF ALASKA
(RECEIVE)

VANDENBURG AFB, CA
- LLV LAUNCH

TRW SPACE PARK. CA.
-SPACECRAFT BUS
-HSI PAYLOAD
-HSI DATA ANALYSIS
-DEMONSTRATION RESULTS ANALYSIS

FUTURE HBCU NETWORK
-CLARK ATLANTA
-HAMPTON UNIV.
-JACKSON ST.
-MORGAN ST.

NASA STENNIS, MS
- HSI DATA CENTER (LEVEL 1 PROCESSING)
- DISTRIBUTION TO USERS
- BACKUP OPERATIONS

TRW (CHANTILLY, VA)
- SSTI PROGRAM OFFICES
- ORBITAL OPERATIONS
- MISSION DATA ARCHIVE AND DISTRIBUTION

NASAGODDARD, MD
- LEISA DATA PROCESSING
- DEMONSTRATION RESULTS ANALYSIS

NASA LANGLEY, VA
- DEMONSTRATION RESULTS ANALYSIS

NASA DSN, WALLOPS
- EARLY ORBIT OPS AND CONTINGENCY

SSTI Technical Team

TRW	Prime Contractor, Spacecraft Bus, HSI Payload, Applications
Jackson & Tull	Flight Electronics, Harness, AT&L Support, HBCU Lead
Lockheed (LLV)	Launch Vehicle
Harris	Ground Segment IPDT Leader
Symbiont	Flight and Test Software
Hughes (HDOS)	Miniaturized Startracker
Gardner	Satellite Engineering, Public School Lead
Microcosm	Autonomous Orbit Maintenance Software
Allied	Ground Operations
UC Berkley	Ultraviolet Cosmic Backround Experiment Payload
Univ. of Alaska	Downlink Communications
NASA Goddard	LEISA Payload, Data Compression, Technology Demo's
NASA Langley	FODB and 1553 Interface, Cloud Rejection
NASA Stennis	Advanced Data Applications, Data Archive
NASA Lewis	Advanced Power Experiment
NASA JPL	Advanced Processor Experiment

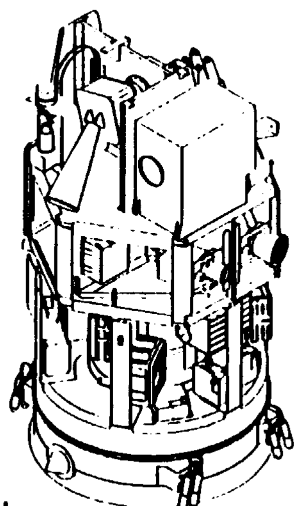
SSTI

Major Accomplishments

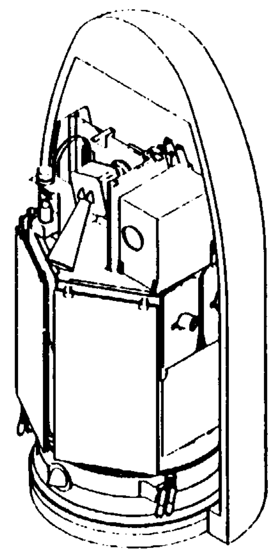
- Established Integrated Product Team with Subs, NASA Centers
- Established On-going Applications Group
  - Early start enabled feedback into the design process
- Completed design audits and reviews per ATP schedule
- Long Lead Parts design freeze, parts on order
- Technical Risk mitigation redesigns incorporated
  - Revised FODB network, OBC reconfiguration, Solar array, Tx sizing
- Incorporated Program change to longer mission life, better user utility
  - More robust Spacecraft bus and HSI Payload
    - » Larger Arrays, batteries, HSI Payload Redundancy, fuel
    - » Improved Payload data collection system
      - Facilitates On-board and ground processing
      - Provides for greater number of images
  - Satellite growth to accommodate these improvements led to change in LV from Pegasus XL to LLV

SSTI as Awarded

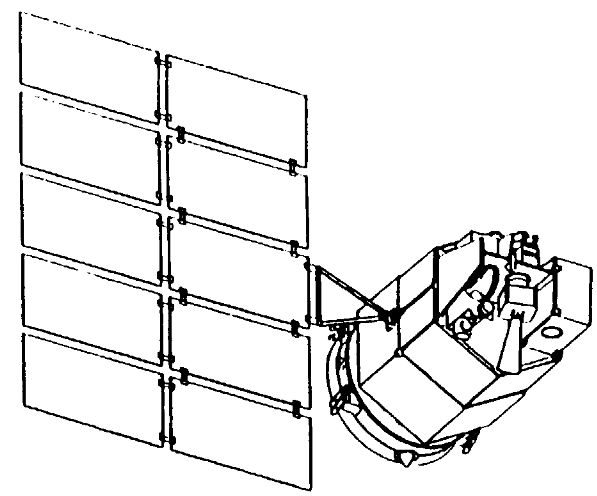
April 94



- 37 GHz
- Single Wing Array
- Pegasus XL Launch Vehicle

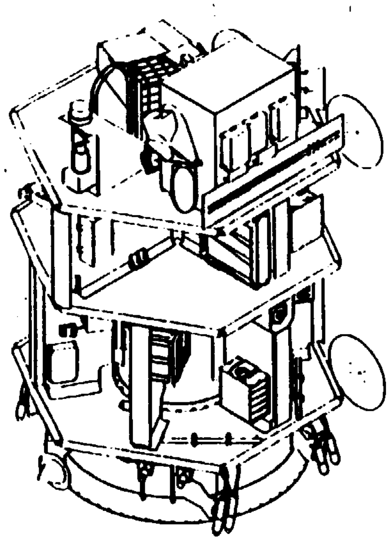


Pegasus XL

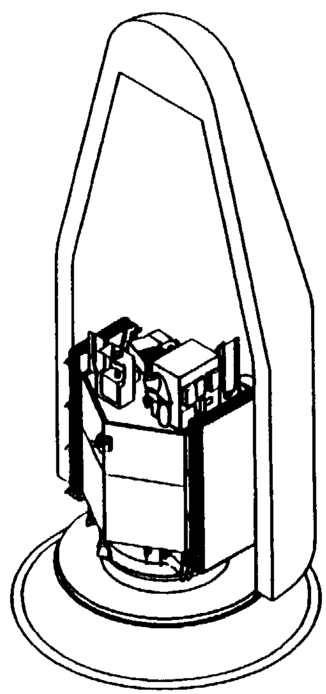


- **Final SSTI design as proposed**
- **A proposed payload requireing an anti-sun orientation deleted late in the proposal**
  - **No time to re-design; Submitted "as-is"**
    - **Anti sun orientation not required for remaining payloads**
- **Satellite weight; 704lbs (Bus 496), OAP 300W, 600W GAs/Ge Single wing Array; 3 years of consumables**

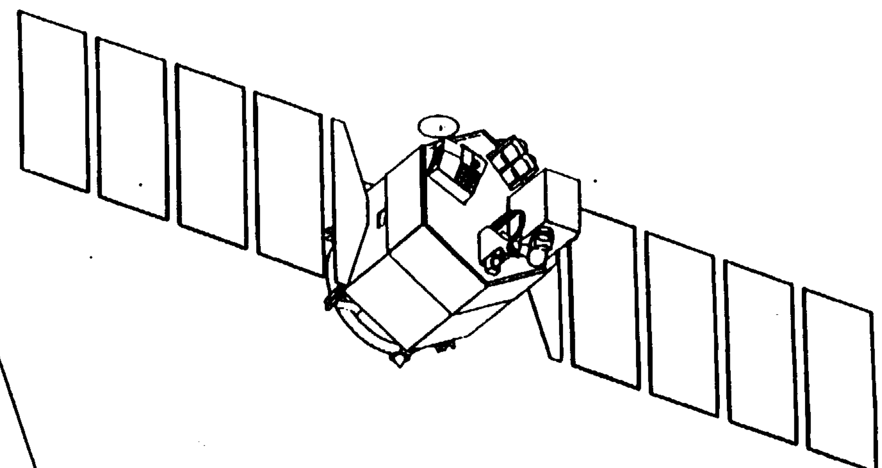
SSTI LLV Design
(17 Jan. 95)



- Wider avionics Module
- Dual Wing Array
- LLV Launch Vehicle



LLV



-Deleted NOAA 37Ghz Payload (not funded)
-Added 5 year design goal
  -Additional fuel, larger arrays & batteries, hardening
  -Selective Payload redundancy and Hardening
  -New Satellite weight of 850lbs (wet)
  -Launch Vehicle changed to LLV
    -Added weight exceeds Pegasus capability
    -AB600 Avionics "Webs" extended 4" to enhance thermal design and array size
    -Array trades; Flat pack (shown) vs Wrap Around

TRW ("Lewis") SSTI Design Reviews

- * ATP; Review of negotiated BAFO technical Baseline (7/11-15)
- * Level 1&2 Design Reviews; Technical Concept Design Reviews (7/22-24)
- * System Design Audit; Technical Implementation review (8/9-10)
- * HSI Payload Functional Review; Technical & Process review (8/6)
  - Comprehensive technical and process review of HSI Payload
- * Incremental Design Audit #1; Payloads, Tech Demo's, Bus Changes (10/13)
  - Detailed Design Review of all SSTI Payloads and Tech Demo's
  - Review of Spacecraft Changes since ATP; Long Lead Parts order
- * SSTI Programmatic Review; TRW audit of SSTI Program (11/16-12/8)
  - Comprehensive review of SSTI Methodology, Programmatics, Technical Approach
- * Incremental Design Audit #2; Spacecraft Bus (12/6&7)
- -> SSTI Program Critical Design Audit (1/17-19)
  - CDA of all SSTI Subsystems and Program Elements
- SSTI Element CDA's; Tailored to subsystem/function development
  - Held by element when appropiate to support development fabrication, and integration

*Completed, ->This Review

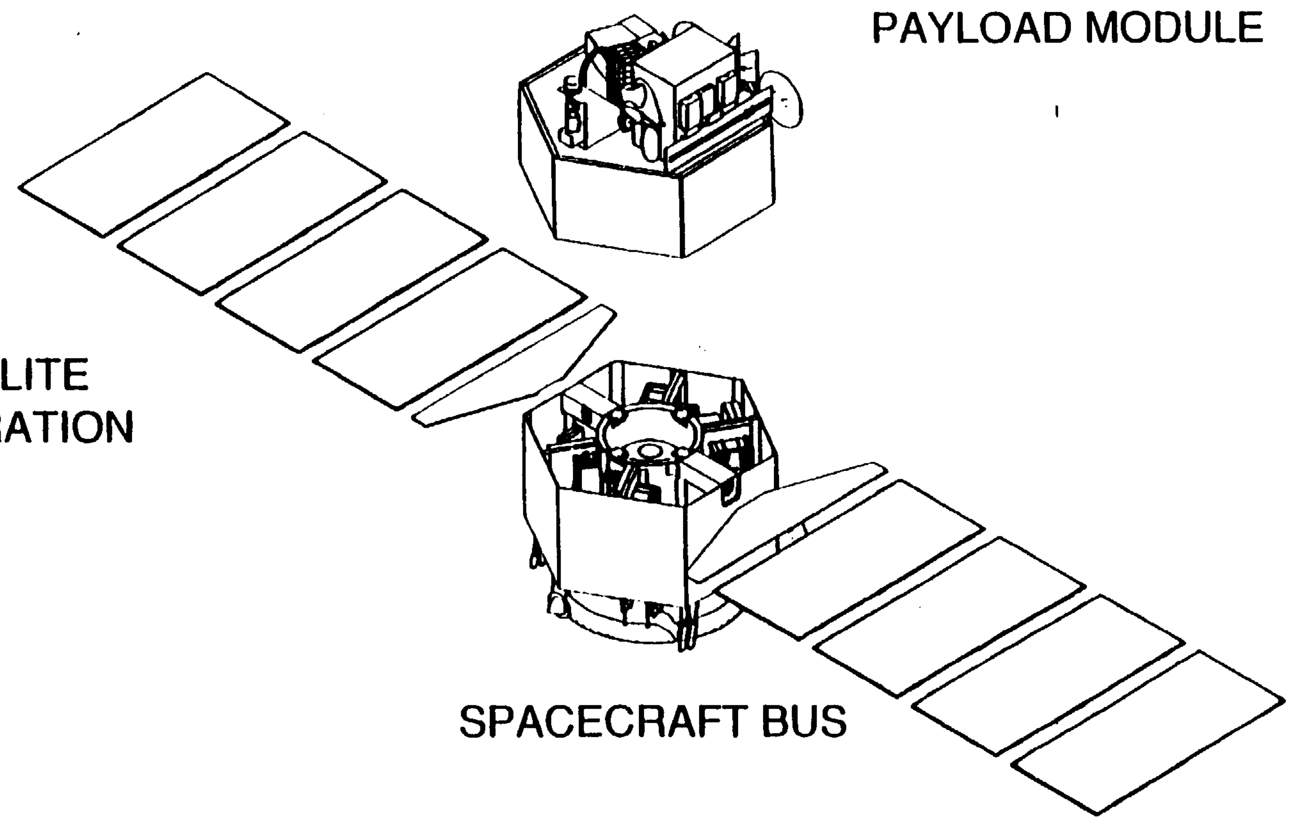
SSTI Programmatic Review

- Programmatic Audit of the SSTI Program
  - Ensures comprehensive TRW review; Technical/Methods/Program
  - TQM Process to ensure sound design and processes
    - » Lessons Learned, Application of new initiatives, "heads up" recommendations
  - Chaired by the TRW S&EG V.P. and Chief Engineer
    - » Reviewers from all S&EG Divisions and Disciplines
  - Recommended for all TRW Satellite Programs (NASA, DoD, Others)
- Objectives; -Conformance with Best/Appropiate Company Practices
  - -Identify Process discrepencies and improvements
  - -Identify Product Areas requiring corrective action
  - -Identify Targets for risk mitigation
- Recommendations in review and incorporation into the Program
  - Within SSTI Programmatic Constraints

TRW SSTI Satellite Design

- TRW collaborated with NASA Centers to develop the SSTI Design
- Recommended Approach;
  - High reliability, fully redundent, operational Spacecraft Bus
    - » Facilitated rapid change to mission lifetime extension
  - Multiple Payloads and supporting Advanced Technology demonstrations
    - » Demonstrate capabilities/performance; single strung, minimal hardness
- TRW SSTI Bus integrates subsystems and Technologies from Brilliant Pebbles (BP), TOMS-EP, and TRW's Advanced Bus (TRW-AB) developments
  - BP and TRW-AB provide advanced technology
    - » Developed and tested on Contract (BP) or TRW IRADS (TRW-AB AB600)
  - TOMS provides mature, reliable, flight tested subsystems and units
- The TRW SSTI primary payload is the TRW Hyperspectral Imager (HSI)
  - Provides the driving mission and satellite requirements
- The TRW SSTI spacecraft carries the GSFC LEISA and UCB UCB Payloads
  - Supporting Astrophysics, Earth Observation, Interplanetary
    - » Current applications and future mission demonstrations

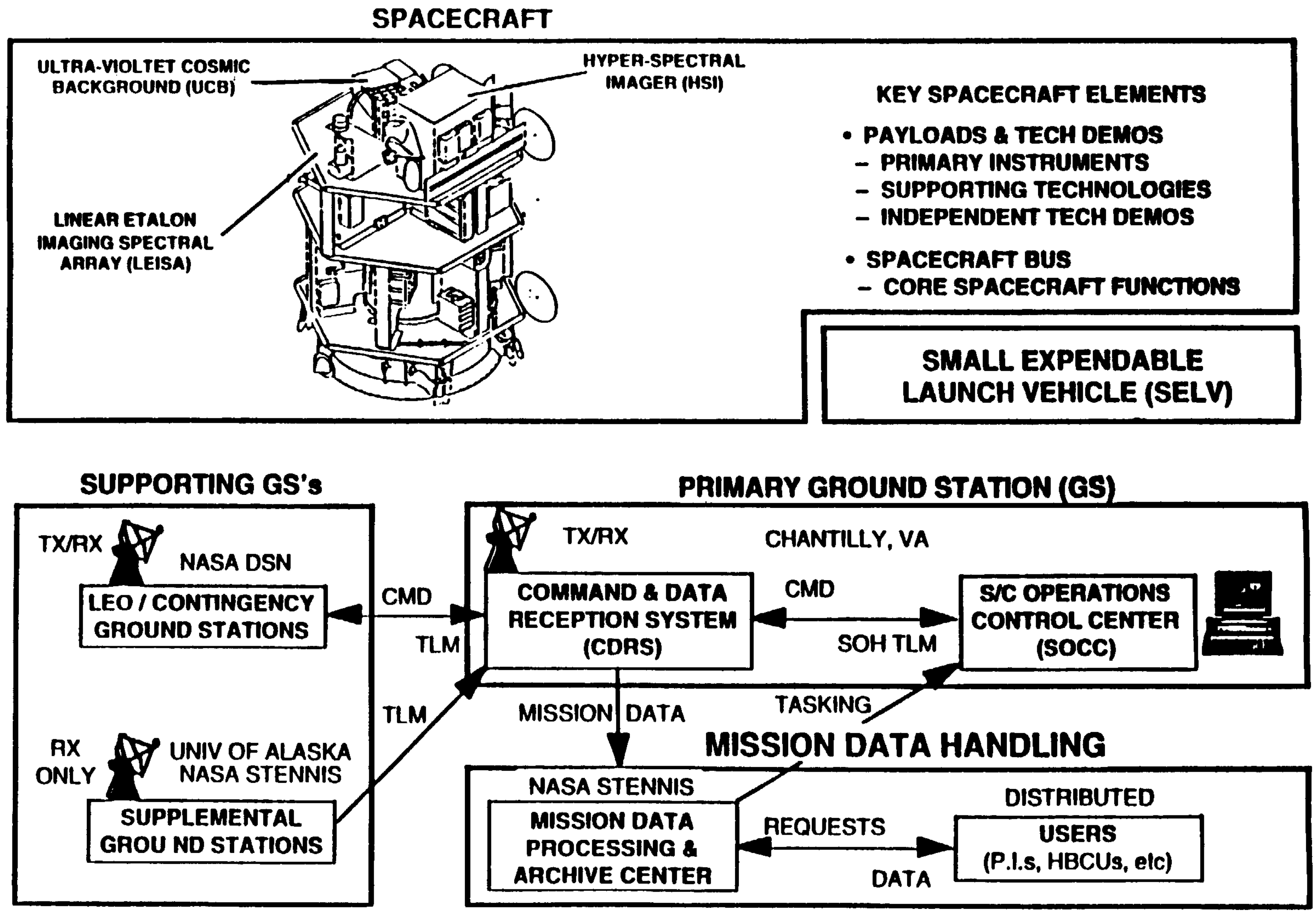
SSTI Satellite Elements



Technical Overview

K. Biber/S. Taylor

SSTI-Lewis System
Functional Block Diagram



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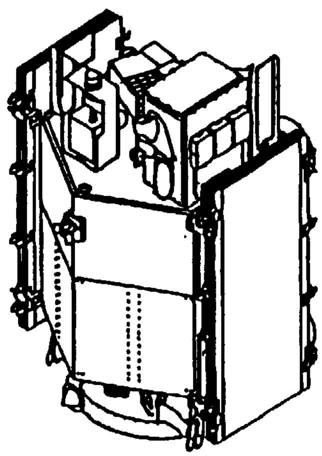
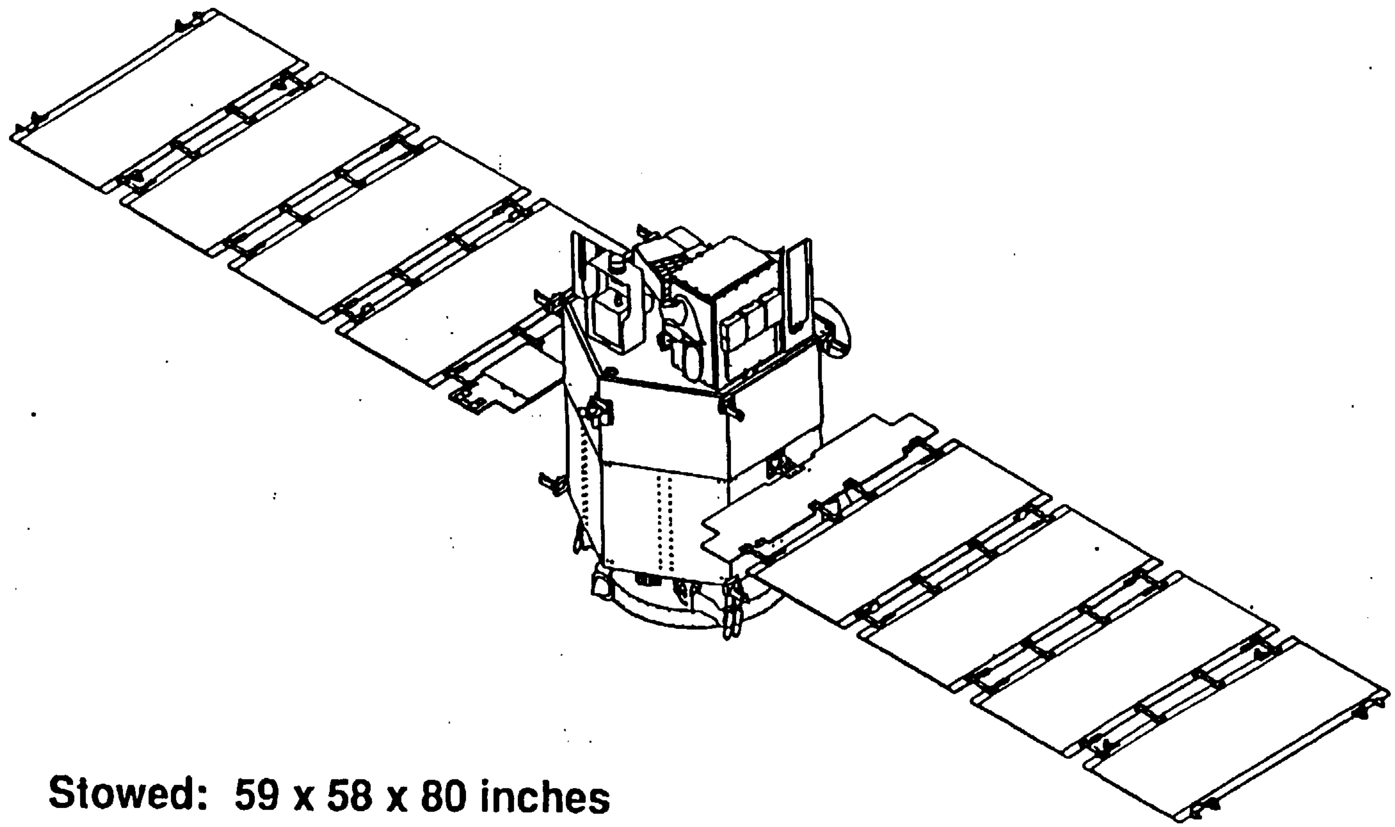
Integrated Design Characteristics





Stowed: 59 x 58 x 80 inches
Deployed: 327 x 59 x 80 inches
Weight: 850 lbs
Power: 740 W EOL (5 yrs)
Orbit: 523km x 94.7 degrees

Payload Instruments

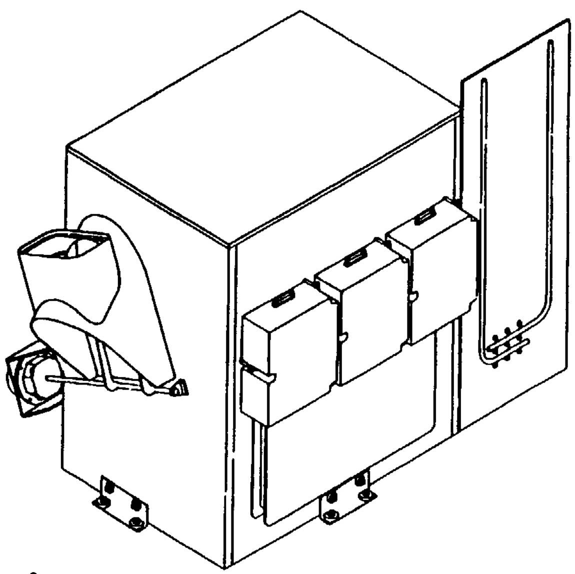
- Hyper-Spectral Imager (HSI)
  - 384-Band, Visible/IR Earth Imaging System,
  - High Ground Resolution: 30 m Multispectral, 5 m Panchromatic
  - Includes In-Flight Calibration Subsystem
  - Broad Application Data

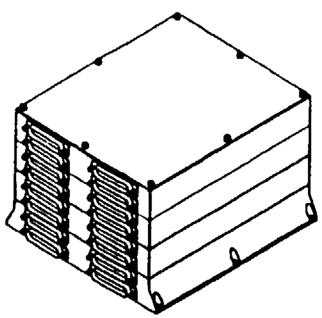
- Linear Etalon Imaging Spectral Array (LEISA)
  - 256-Channel Near IR/SWIR Earth Imaging System
  - Broad-Area Earth-Sensing System; 300 m Resolution
  - Complements HSI
  - Demonstration For Pluto Flyby Mission

- Ultraviolet Cosmic Background Spectrometer (UCB)
  - 58-95 nm Grating Spectrometer For Measurement Of Astrophysical Component Of EUV Cosmic Background
  - Observe Local Inter-stellar Medium
  - Measure Energetic Geocoronal Plasma Phenomena
  - Instrument Sensitivity Up To 1000 Times Greater Than Previous Work, With Spectral Resolution Up To Eight Times Greater

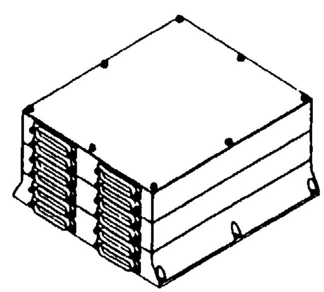
Hyperspectral Imager Summary

HSI Sensor Assembly (HSA)





HSI Control Electronics (HCE)



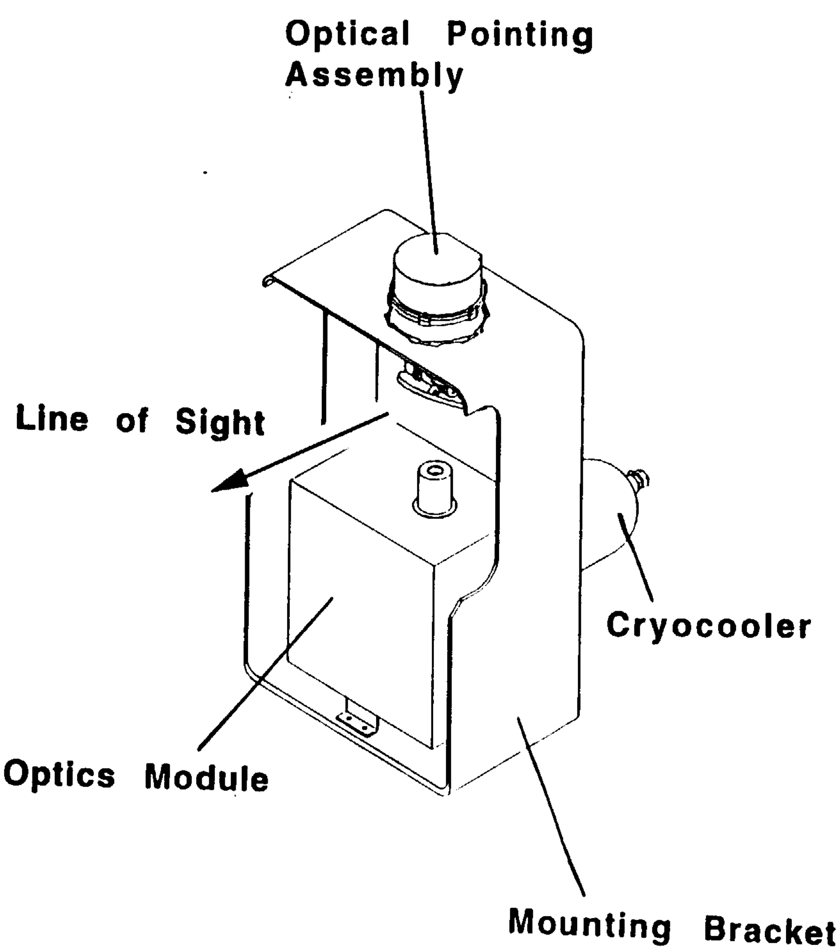
HSI Power Electronics (HPE)

- Pushbroom scanned, body pointed imaging spectrometer and panchromatic camera
  - 384 selectable bands, 0.4 - 2.5 μm
  - 5 m Pan, 30 m Hyperspectral (HS) Ground Sample Distance (GSD)*
  - 6% radiometric accuracy, 1σ, HS
- In-flight calibration subsystem
- Vibration damped, Pulse tube cryocooler
- Weight - 35 kg
- Power - 56 W, avg
- Data storage, compression, etc. provided by spacecraft

* @ nadir, 523 km altitude

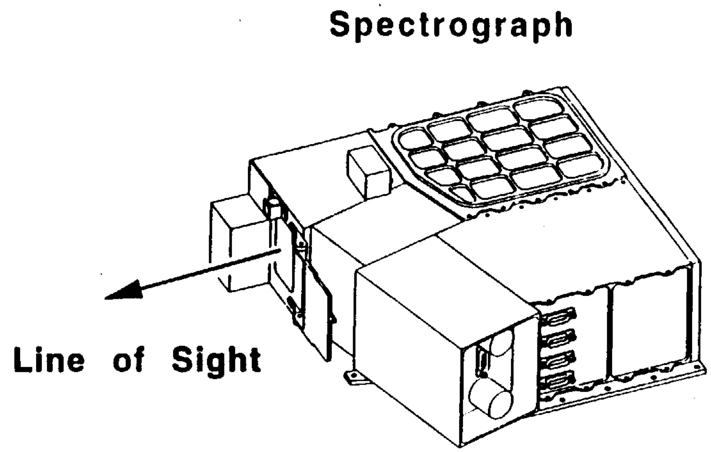
CDA. 2

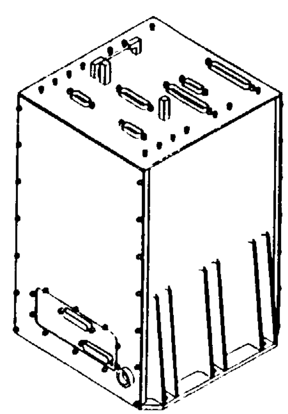
Linear Etalon Imaging Spectral Array (LEISA) Summary



- Pushbroom scan
- Linear variable etalon spectrometer
  - 256x256 staring FPA
  - 256 bands, 1.0 - 2.5 μm, resolving power 250
- 0.57 mrad pixel, 0.84° FOV (300 m, 76.8 km @ nadir)
- OPA expands field of regard
  - +12°/-28° pitch, ±85° roll (FOV center)
- Electronics board in GEM
- Total mass 7.1 kg, total power 40 W
  - Includes GEM board
- Data rate ≤32 Mbits/sec
- Data compression provided by spacecraft

Ultraviolet Cosmic Background Spectrometer (UCB) Summary





- Extreme ultraviolet spectrometer
- Unique grating for diffuse emissions
- 8.4° x 25.6° field of view
- Covers 55 - 105 nm
  - 0.5 nm resolution @ 58.5 - 95.0 nm
- High sensitivity,
  - $\leq$ 2k ph/sec-cm^2-sr @ 100 hrs. observation
- Total mass 17.8 kg, total power 20.5 W
- Average data rate 10 Mbytes/30 minutes

SSTI

TECHNOLOGY DEMONSTRATIONS
(1 OF 2)

TECHNOLOGY	P.I.	SUMMARY
Data Compression (Lossless and Lossy)	GSFC	Demonstrate On-Orbit Lossless and Lossy Compression Of Image Data
S/C Loads & Acoustic Measurements (SLAM)	GSFC	Measure Spacecraft Environment During Launch Sequence
Radiation & SEU Monitoring	LaRC	Measure LET Spectrum w/ Gas Proportional Counter; Correl. With Processor Mem.SEUs
GPS Attitude Determination	GSFC	Demonstrate 0.15 deg Attitude Det. By Interferometric Measurement Of GPS Signal
Wide FOV Star Tracker	Hughes	Demonstrate 20-deg FOV Star Tracker With 6-Star Capability
Micromachined Accelerometers	U. of Cincinnati	Demonstrate Use Of Micromachined Technology For S/C Loads Measurements
R-3000 Processor and 4-Gbit Solid State Recorder	TRW	Demonstrate On-orbit Operation of R-3000 Processor/SSR Combination
Fiber Optic Data Bus	HI/TRW	Demo. On-orbit Oper. of High Speed FODB
Pulse-Tube Cryocooler	TRW	Demonstrate On-orbit Operation of Compact, Low-Vibration Cryocooler
Optical Pointing Assembly	TRW	Demonstrate On Orbit Operation of Precision Steerable Mirror

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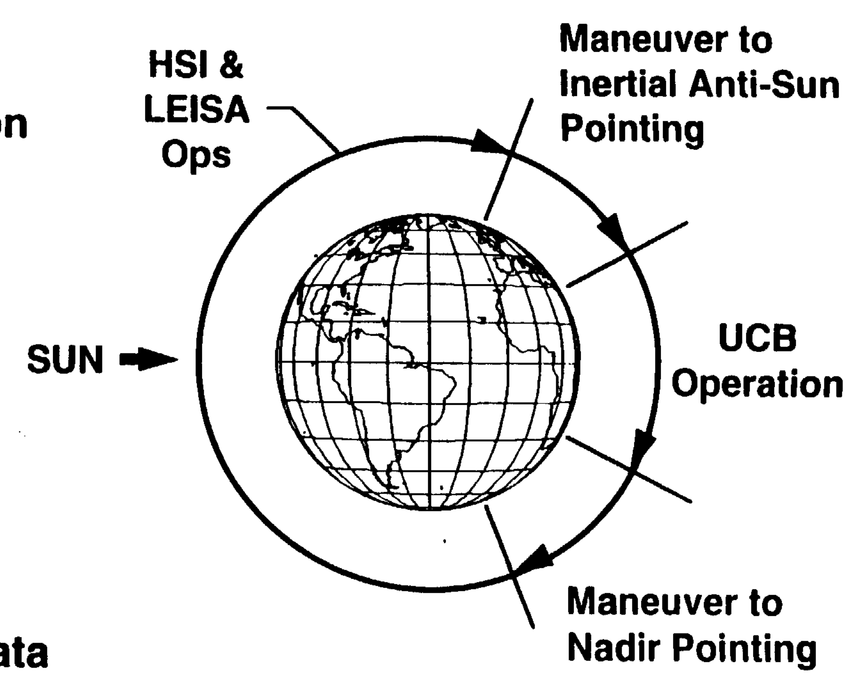
TECHNOLOGY DEMONSTRATIONS
(2 OF 2)

TECHNOLOGY	P.I.	SUMMARY
Advanced Solar Cell Experiment (ASCE)	GSFC/ TRW	Measure On-Orbit Performance Of Multijunction GaAs and Amorphous Silicon Solar Cells
Metal Matrix Composition Heat Strap	GSFC	Measure On-Orbit Performance Of Graphite/Aluminum Matrix For Thermal Control
Magnetically Suspended Reaction Wheel	TRW	Demonstrate On-Orbit Performance Of Magnetically-Suspended RW
Autonomous Orbit Control	Microcosm	Demonstrate On-orbit Autonomous Maintenance (ΔV) Capability (Calc. Only)
Cloud/Feature Identification	LaRC	Use HSI and LEISA Data To Develop Algorithms For Cloud, Snow, etc. Ident.
Enhanced ACS Expt.	LaRC	Demonstrate MIMO Attitude Control S/W On-orbit (Out-Year Expt.)
On-orbit Identification Expt.	LaRC	Assess Spacecraft Dynamic Performance
EPS Regulator	LeRC	Measure On-Orbit Performance Of Regulator Designed For Small Satellites
Advanced Packaging Expt.	JPL/TRW	Demonstrate On-orbit Operation of RH-32 Processor Using MCM Technology

On-Orbit Operations

- HSI & LEISA operate during daylight
  - HSI: $\pm$ 0-22 deg roll offset from nadir
  - LEISA: 'look ahead' nominal operation using pointing mirror
- UCB operates during eclipse
  - Inertial, anti-sun pointed
- Many windows for Tech Demo operation
  - Background low-rate, low-volume
  - No special maneuvers
- Store and forward concept for mission data and historical telemetry
  - Primary ground station at Chantilly, VA
  - Supplemental 'bent pipe' ground station planned at Fairbanks, AK



Spacecraft Bus

Design Changes Related to 5 Year Mission Goal

- Solar array power output increased to provide full payload power for 3+ years and full HSI mission power for 5+ years
- Designs of wear-out items (Reaction Wheels) and radiation sensitive equipment (electronic units) modified to meet longer mission life
- Battery cell modules and Battery/Propulsion Module redesigned for longer battery life (enhanced cell-to-cell thermal tracking and lower end-of-life battery temperature) - perturbing heat sources (Solar Array Regulators) moved up to Avionics Module
- Avionics and Payload Module diameters increased by 8 inches to expand equipment accommodation, thermal radiator areas, and AI&T accessibility - structure dimensions more closely approximate AB600 structural test model

Other Key Design Changes

- Non-redundant payload-dedicated computer (Data Compression Unit) deleted - all flight software functions (bus, technology demonstrations, and instrument support) and data compression boards now incorporated into redundant on-board computers
- Redundant hardwire interfaces incorporated to back up Fiber Optic Data Bus

SSTI

Spacecraft Bus Characteristics

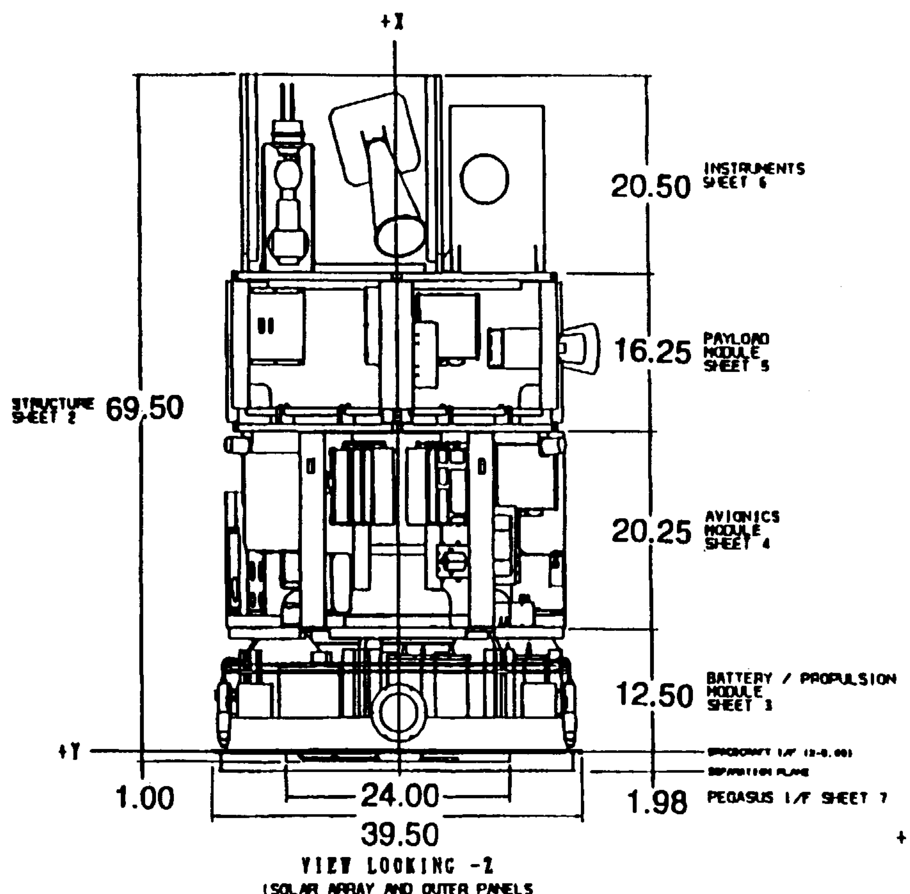
TRW

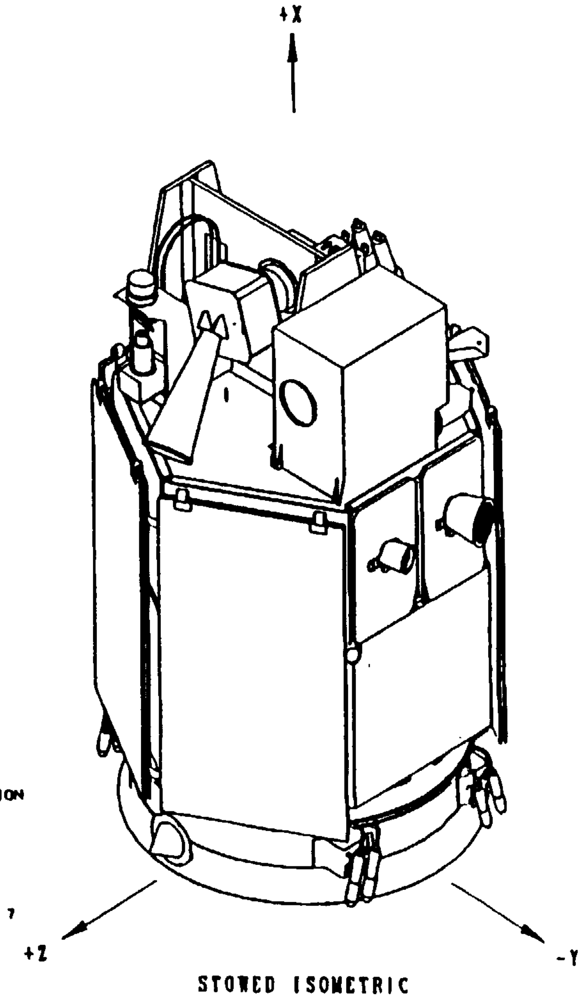
	As Proposed For Pegasus XL	As Designed For LLV
Design Life	3+ years	5+ years
Predicted Reliability (yr 3)	0.93	0.92
(yr 5)	-	0.83
Est. Bus Weight * (at launch)	176 Kg	218 Kg
Bus Mass Fraction (dry)	63.6 %	63.1 %
Propellant Load	30.0 Kg	42.1 Kg
Solar Array Output (yr 1)	600 W	784 W
(yr 3)	550 W	762 W
(yr 5)	-	740 W
Energy Storage (CPV NiH_2)	18 AH	23 AH
Battery Depth of Discharge	0.3	0.3
Avg. Bus Operating Power	122 W	165 W
Avg. Payload Power (yr 1)	129 W **	172 W
(yr 3)	129 W **	172 W
(yr 5)	-	162 W

* w/o Payload Module

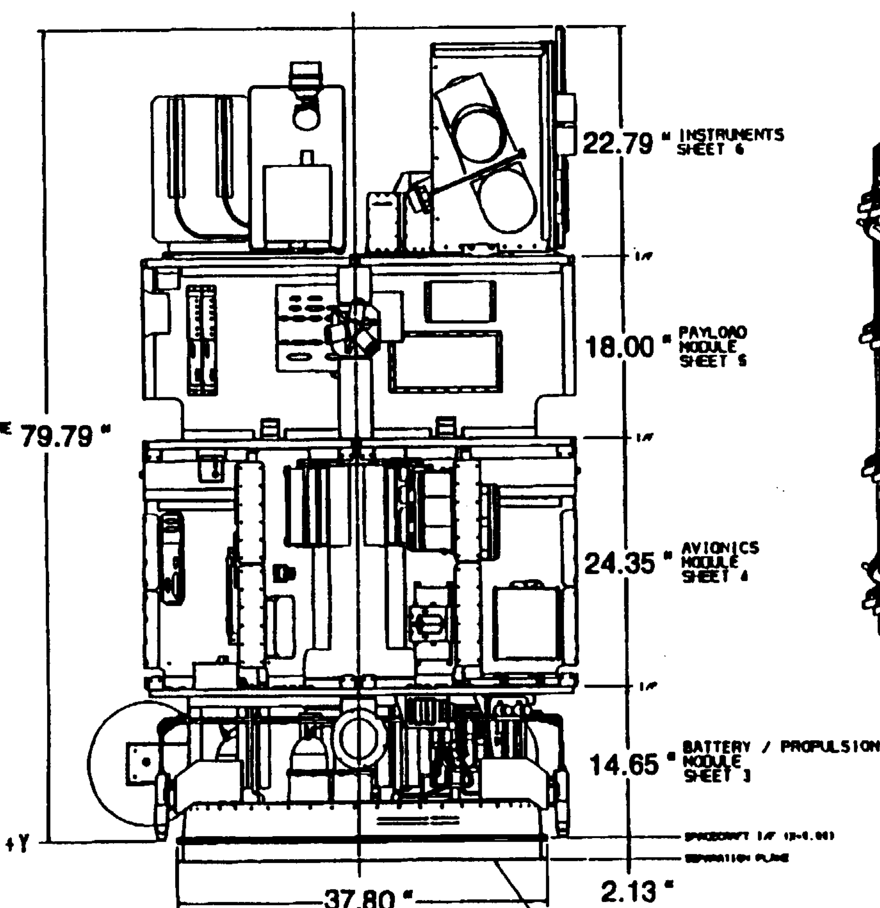
** includes Data Compression Unit (19 W)

Spacecraft Configuration
(As Proposed)

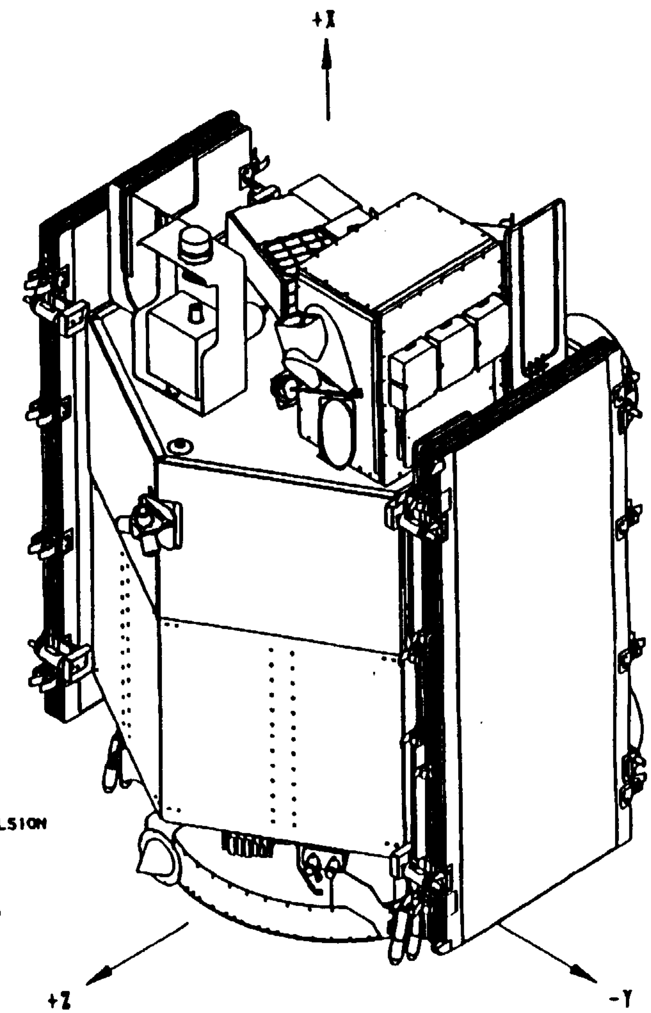




Spacecraft Configuration (As Designed)



VIEW LOOKING -Z
(SOLAR ARRAY AND OUTER PANELS REMOVED FOR CLARITY)



STOWED ISOMETRIC

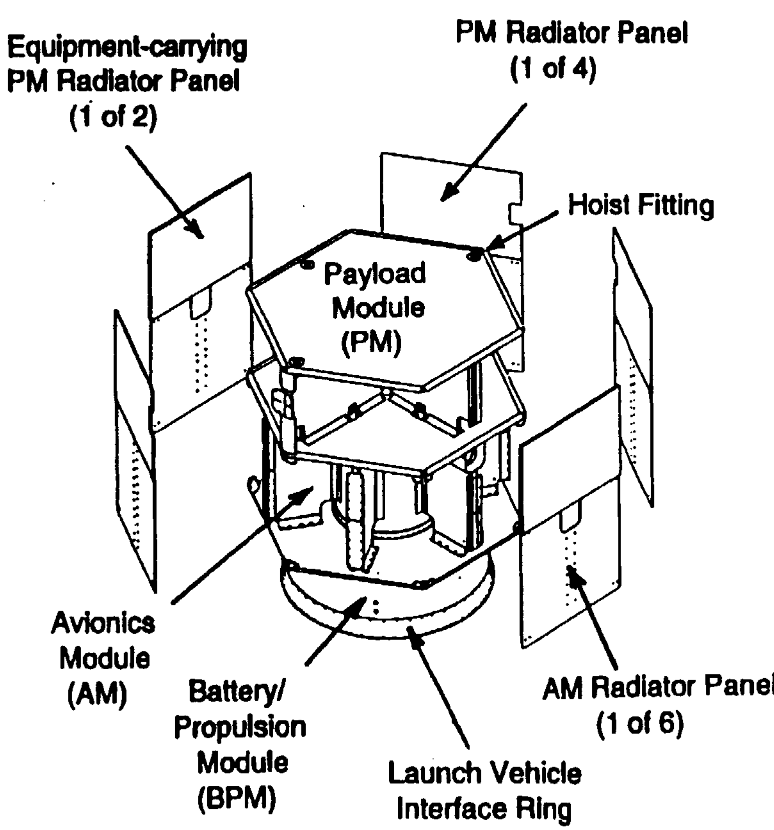
REVISED: 01/14/95

SSTI CONFIGURATION LAYOUT

L305501

SSTI

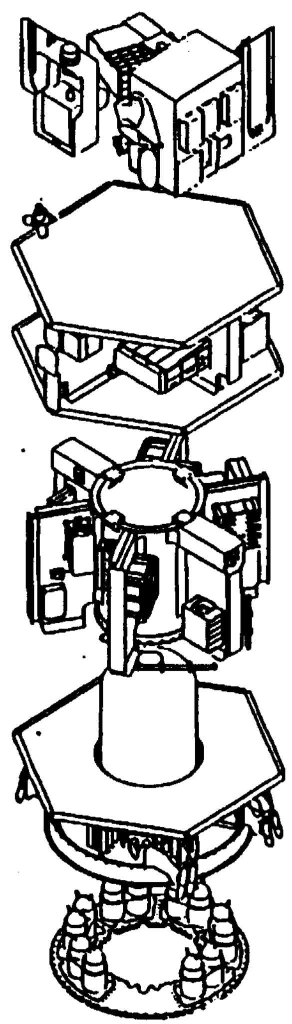
Structure and Mechanisms Subsystem



Structure Configuration

- Adaptation of Existing AB600 Structure
  - Full-scale flight-like structure built and successfully tested statically and dynamically in 1993/1994
- Modular Design
  - Modular structure with bolted joints between Battery/ Propulsion Module (BPM) and Avionics Module (AM) and between AM and Payload Module (PM)
  - Designed for accessibility and parallel integration
  - Capability for separate battery assembly installation
- Efficient Load Paths
  - Central cylinder of AM provides primary load path between PM and BPM
  - BPM internal shear panels transfer loads from inner cylinder to outer cylinder
  - BPM outer cylinder bolted to LLV interface ring
- Integrated Structural and Thermal Design
  - Equipment panels attached to structure via flex angles to avoid peel failures cause by elastic deformation of central cylinder under launch loads
  - Hybridized panel facesheet laminates incorporate high-conductivity, low strength pitch fibers (K1100) and low-conductivity, high strength PAN fibers (M60J)
- Ease of Manufacturing
  - Simple shapes: cylinders and flat panels
  - GFRP facesheet/honeycomb sandwich construction
- Estimated Weight: 60 Kg

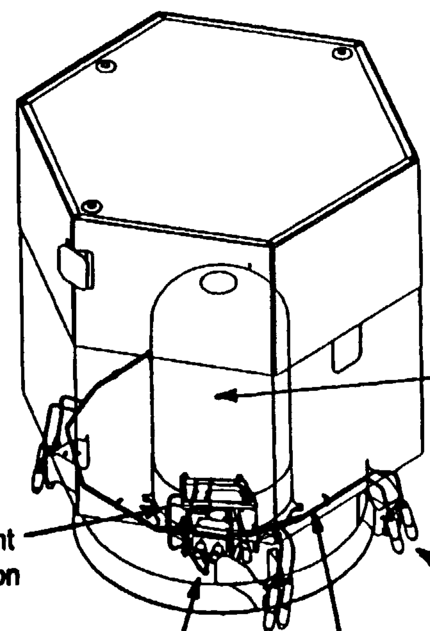
Thermal Control Subsystem



Thermal Control Zones

- Separate Thermal Control Zones
  - Thermal design optimized to minimize heat exchange among spacecraft modules
  - Oriented P100 and K1100 plies added to GFRP equipment panels to enhance heat flow towards module radiator panels
  - T300 facesheets used on BPM for thermal isolation from AM
  - Thermostatically controlled heaters used in orbit transfer mode and to minimize battery temperature excursions over 5 year design life
- Optimized Equipment Locations
  - High-dissipation equipment mounted on module anti-sun sides
  - Equipment mounting on interior panels reduces on-orbit sunlight/eclipse thermal excursions
  - High emittance coatings on equipment and module interiors further equalize compartment temperatures
- Conservative Design
  - Equipment mounted on high-conductivity interior panels
  - Interior panels conductively coupled to bolted-on, rigid, high-conductivity exterior radiator pannels via "dimpled" aluminum foil
  - Heat rejected via white (Z-93) painted radiator panels; excess radiator areas covered with MLI
  - Battery baseplate temperature equalized via heat pipes
- Estimated Weight: 4 Kg
- Orbit-average Power: 11 W

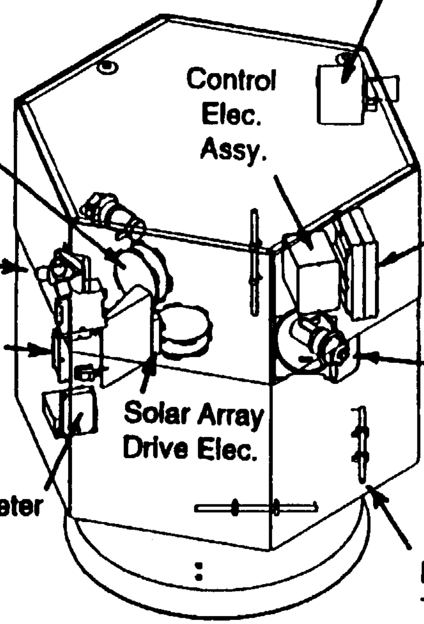
Orbit Adjust Subsystem



OAS Equipment Configuration

- Monopropellant hydrazine blowdown system
  - Provides impulse for orbit transfer, orbit adjust maneuvers (drag make-up), safe haven mode and back-up attitude control
  - 80.4 Kg propellant capacity at 4:1 blowdown ratio
  - Blowdown operation for reduced risk, cost, and ground station workload
- Safety Compliance
  - Two fault tolerant to catastrophic leakage during ground operations and launch
  - At least single fault tolerant during all operational modes
  - All welded system; also enhances reliability
- Design to Cost
  - Reduced number of components shortens OAS integration schedule
  - Qualified, flight proven components
  - Modular design permits parallel integration of structure modules; only BPM needed for OAS assembly
  - New technology, short delivery schedule graphite/ epoxy overwrap propellant tank
- Optimized Thruster Locations
  - Thrusters located aft for propellant settling, minimzed plume impingement and contamination
- Estimated Weight: 16 Kg
- Orbit-average Power: 42 W

Guidance, Navigation & Control Subsystem



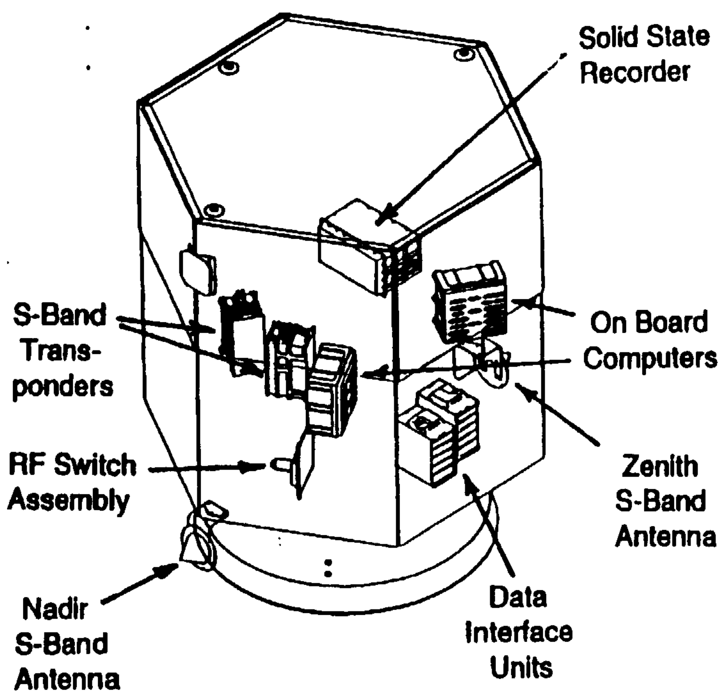
GN&C Equipment Locations

- Principal Functions
  - Attitude determination and 3-axis stabilized, zero-momentum biased attitude control
  - Articulated, single-axis, dual wing solar array drive
  - Instrument pointing
  - Orbit transfer guidance and control
  - Safe haven spacecraft orientation
- Performance - Nadir pointing
  - attitude knowledge (roll, pitch, yaw): 10, 30, 50 arc-sec
  - attitude control (roll, pitch): $\leq$ 0.04°
  - drift rate stability: $\leq$ 10 arc-sec in one second
  - position knowledge: 200 meters
- Performance - Inertial pointing
  - attitude knowledge: $\leq$ 0.25° each axis
  - attitude control: $\leq$ 0.4° each axis
- Functional Implementation
  - GN&C software in On Board Computer
  - reaction wheel for attitude control
  - magnetic torquers/magnetometer to dump momentum
  - gyros to propagate attitude
  - star tracker/earth sensors for attitude updates
  - off-modulated thrusters for orbit transfer/drag makeup
  - stepper motors for solar array rotation
  - GPS receiver + on-board propagator for position knowledge
- Estimated Weight: 34 Kg
- Orbit-average power: 43 W

SSTI

Data Management Subsystem

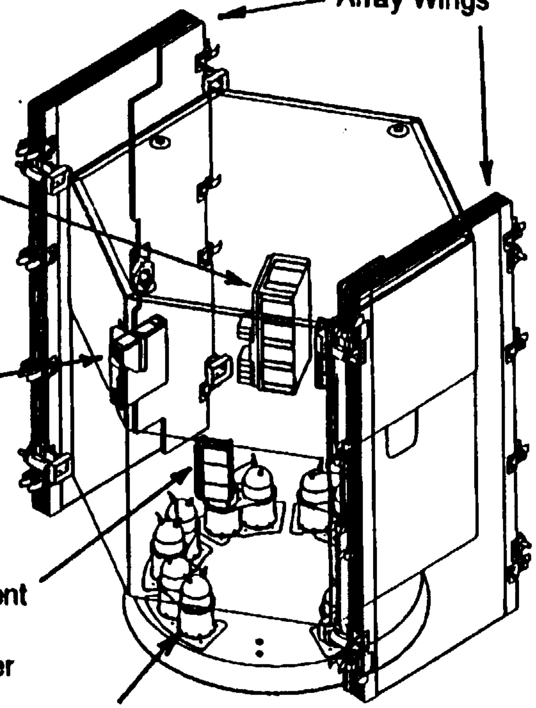
TRW



DMS Equipment Locations

- R3000 On Board Computers
  - $\geq$ 8 MIPS at 16.384 MHz
  - 2 MByte SRAM, 1 MByte EEPROM
- Data Interface Units
  - TT&C, GN&C, OBC and EPDS interface functions
  - Discrete and analog command generation & processing
  - Fault monitoring
- 4 Gigabit Solid State Recorder
  - 440 MBPS data rate
  - Real time data sorting
- Fiber Optic Data Bus
  - 440 MBPS data rate
- 1553B Bus Controller
  - Command distribution and data acquisition
- S-Band Transponders
  - 5 watt RF power output, GSTDN/DSN compatible
  - 2 kbps uplink command rate
  - 8 kbps or 2.048 mbps downlink telemetry,
  - Convolutionally encoded (NASA Std r=1/2, k= 7 Viterbi)
- RF Switching Assembly
  - Omni or nadir-directed RF transmission
  - Transponder transmitter selection
- S-Band Antennas
  - $\geq$ 85%spherical coverage for receiving and transmitting
  - Shaped pattern enhances gain at beam edges
- Estimated Weight: 22 Kg
- Orbit-average Power: 61 W

Electrical Power and Distribution Subsystem

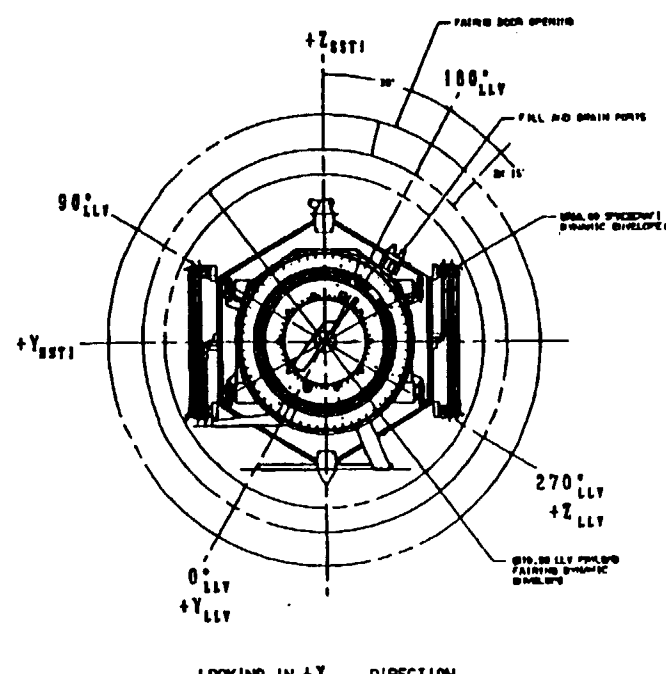


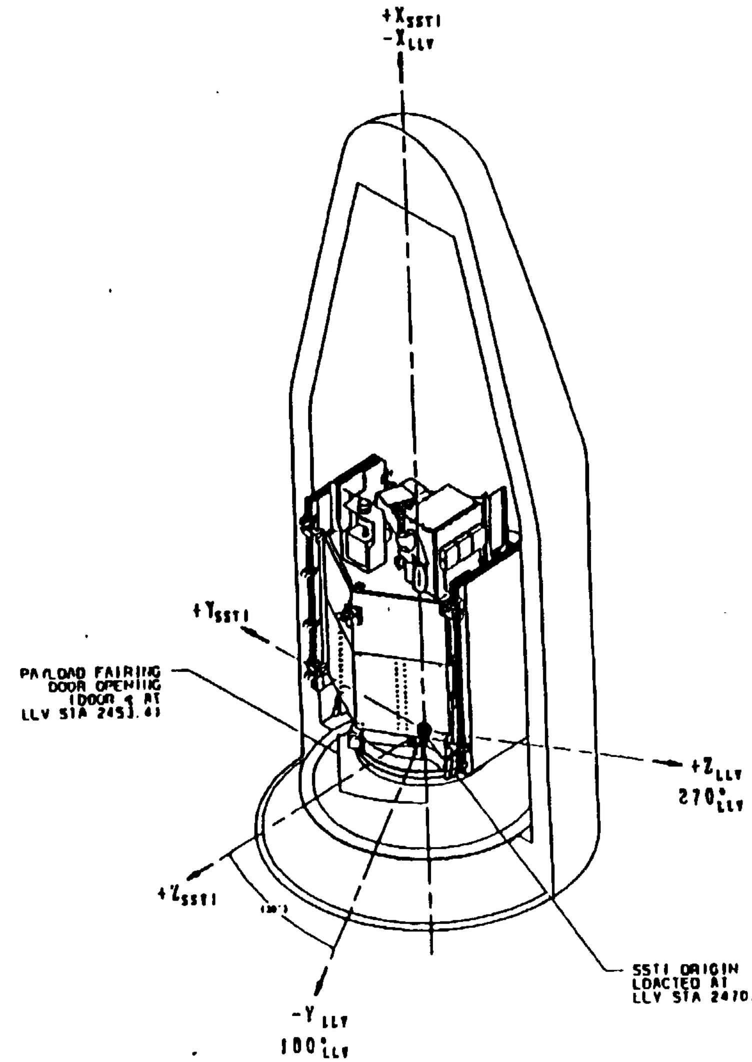
EPDS Equipment Locations

- Power Generation
  - 740 W solar array (at end of 5 years)
  - Si solar cells, CMX cover glass
  - Graphite facesheet/aluminum honeycomb substrate
- Energy Storage
  - 24 (23 AH capacity) cells in 12 2-cell common pressure vessels
  - 5 year design goal (5700 discharge cycles/year)
- Solar Array Regulators
  - Adjust solar array output to provide load power and control battery charging
  - Buck-type converter; duty cycle controlled by computer-generated external command
- Power Control Unit
  - Power control and distribution for all electrical loads
  - Source of secondary power for a limited number of low power spacecraft and payload units
  - Power bus protection against overloads
- Deployment Device Controller
  - Eight redundant control channels operate eight redundant solar array release devices
- Software
  - Controls battery charging
  - Maintains battery state-of-charge data
  - Detects anomalous subsystem behavior
- Estimated Weight: 64 Kg
- Orbit-average Power: 222 W

Spacecraft-to-LLV Interface

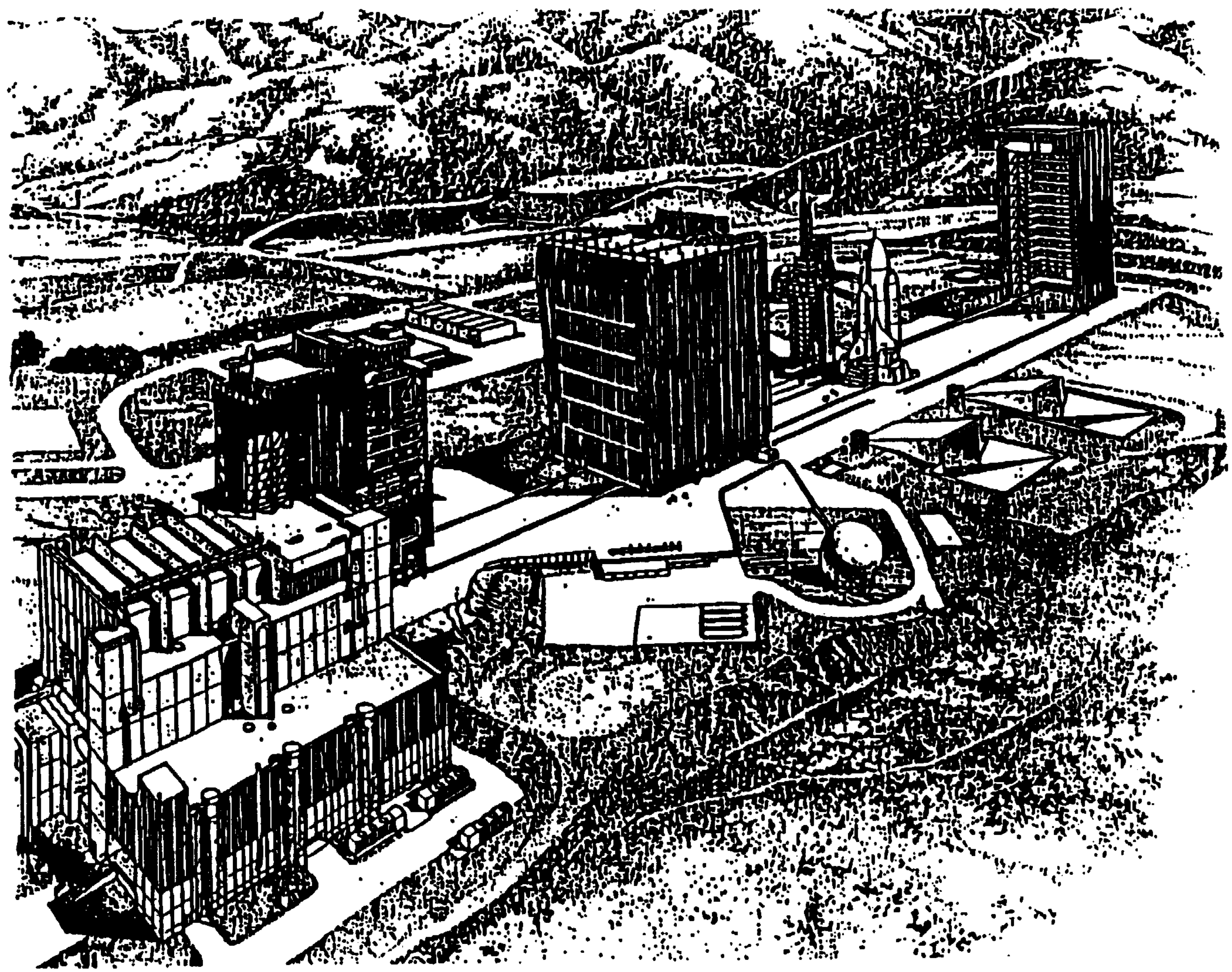
- Fairing door location fits propulsion and electrical IFJs
- Spacecraft has clearance to 78 inch fairing envelope
- Electrical interface to LV is wired to two connectors at separation interface





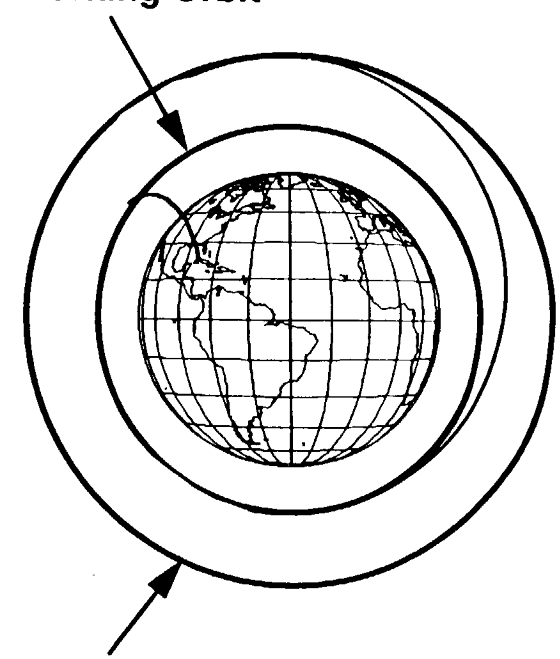
Launch Vehicle Integration
SLC-6

Integration Building



Launch & Insertion

- LLV launch from Vandenberg & insertion into 300-km parking orbit
- Solar array deployment, attitude stabilization, and initial checkout
  - 3-day allowance
- Transfer to 523-km operational orbit using spacecraft propulsion
  - 5-day estimate
- Early-orbit ground support from NASA Deep Space Network (DSN)



SSTI Ground Segment

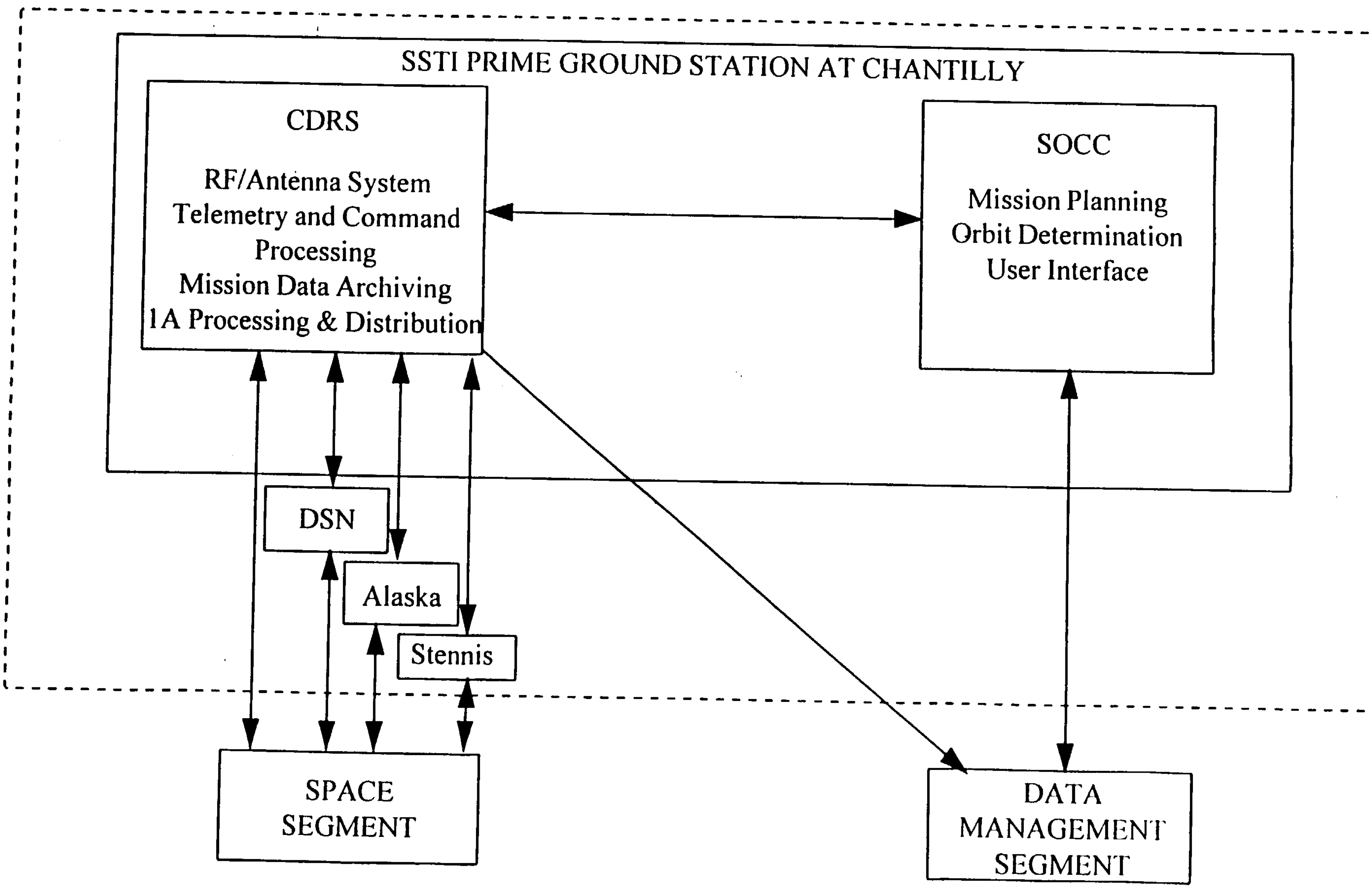
- The prime ground station at Chantilly includes the following
  - CDRS (Command and Data Reception System, Harris Corp): Includes a 12 foot, three axis antenna, all RF uplink/downlink equipment, a Nighthawk realtime computer, GPS time reference, command/telemetry software, and mission data archive and distribution.
  - SOCC (Spacecraft Operations Control Console, TRW SIG): Includes orbit determination software, mission planning tools, and interface to user community/tasking committee.

- DSN (Deep Space Network, NASA): Provides remote command and telemetry sites. Used for initial checkout and available for contingency purposes during normal operations.

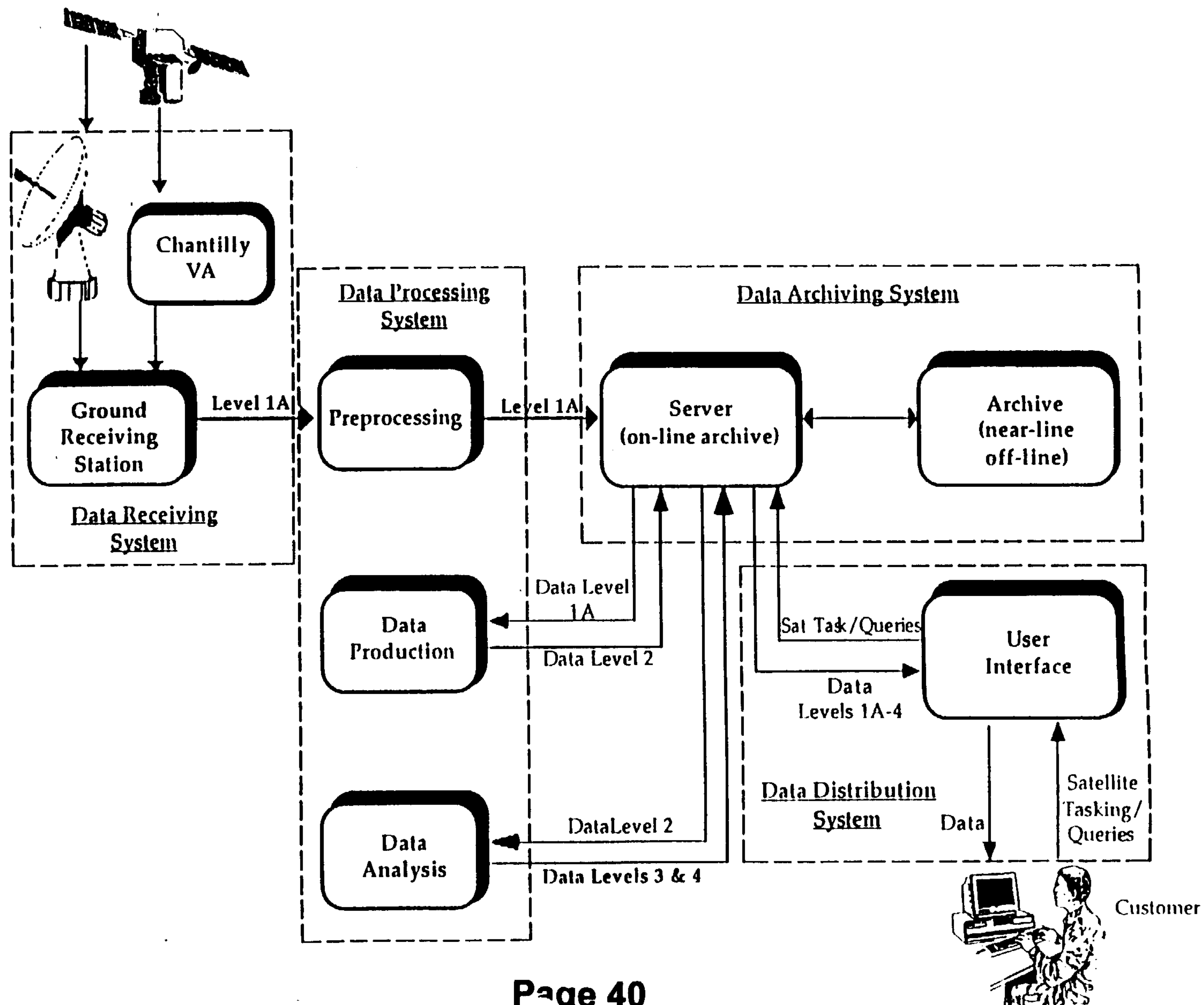
- Alaska (NASA): Provides remote command and telemetry site. Used for initial checkout, normal operations, and contingency operations.

- Stennis (NASA): Provides remote telemetry receive-only site during normal operations.

SSTI GROUND SEGMENT



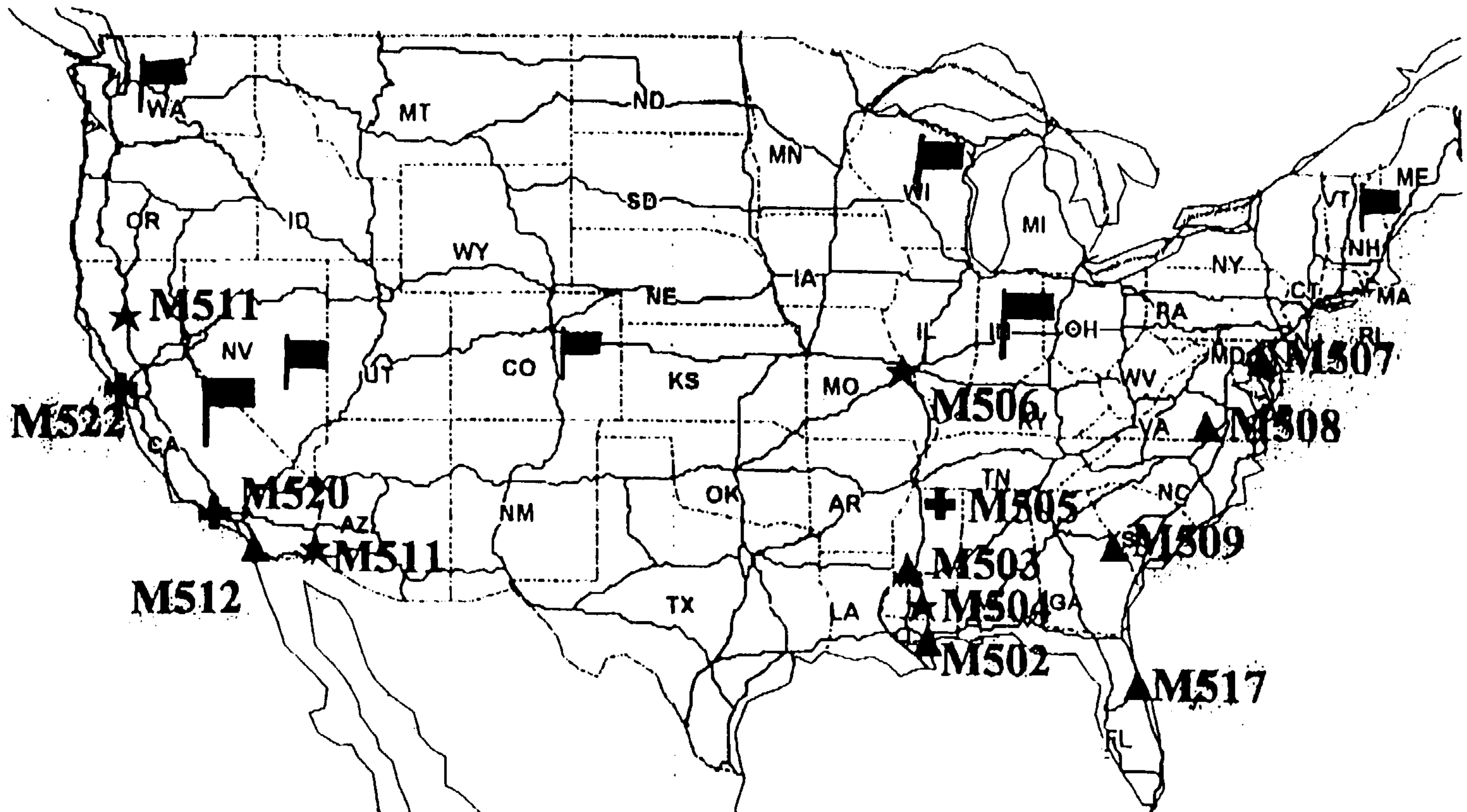
DATA MANAGEMENT SYSTEM OVERVIEW



SSTI

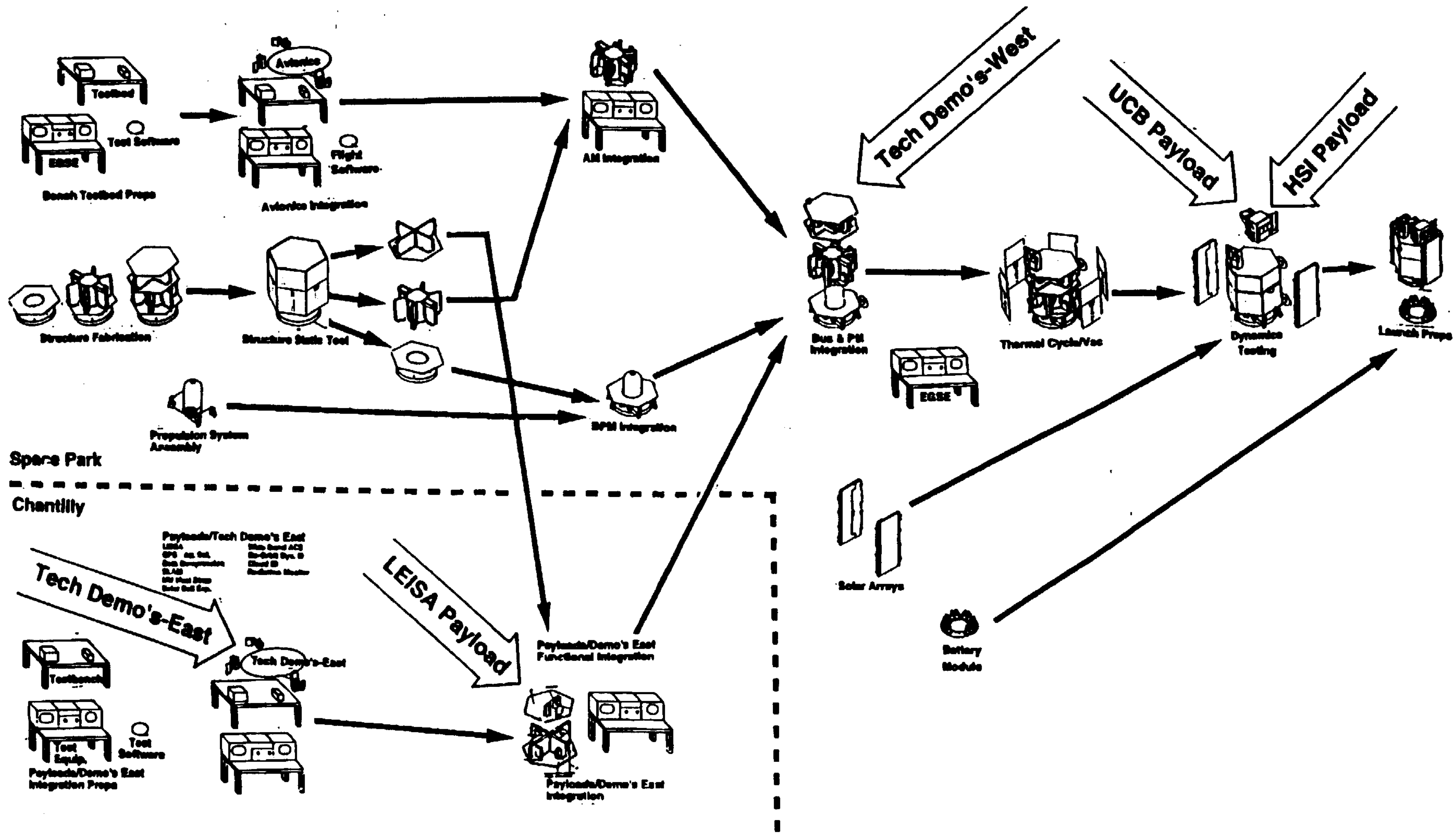
User Applications Overview

TRW

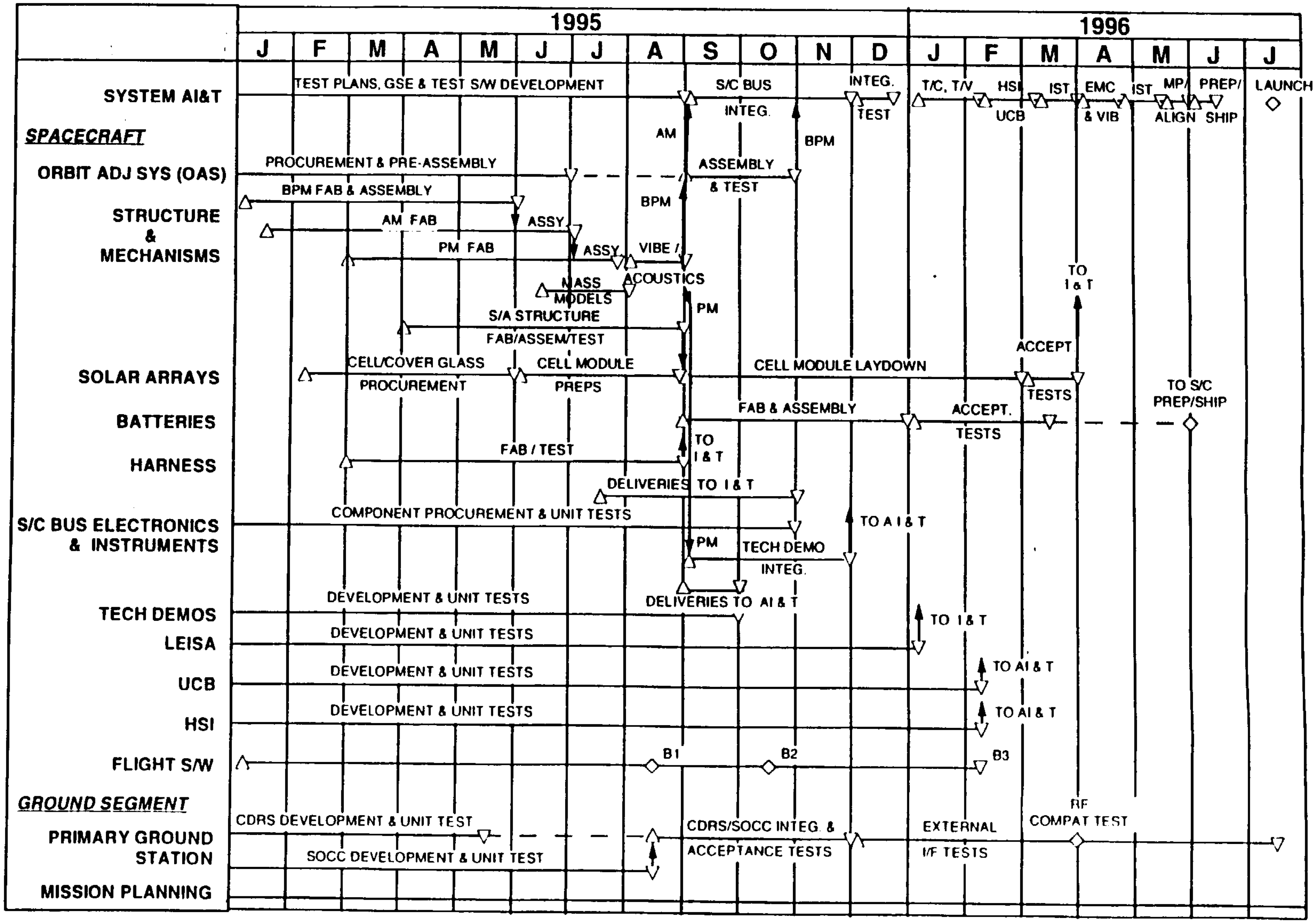


▲science ★ commercial ✚education

Spacecraft Integration Flow



SSTI Schedule



Agenda
System Requirements

• Performance Requirements	Steve Taylor
• System Verification	Ed Belte
• Mission Assurance	Lee Niemela

System Requirements Summary

- User-based mission requirements relatively stable since ATP
  - User requirement for absolute ground-sample position knowledge revisited (changed to 200 m from 125 m)

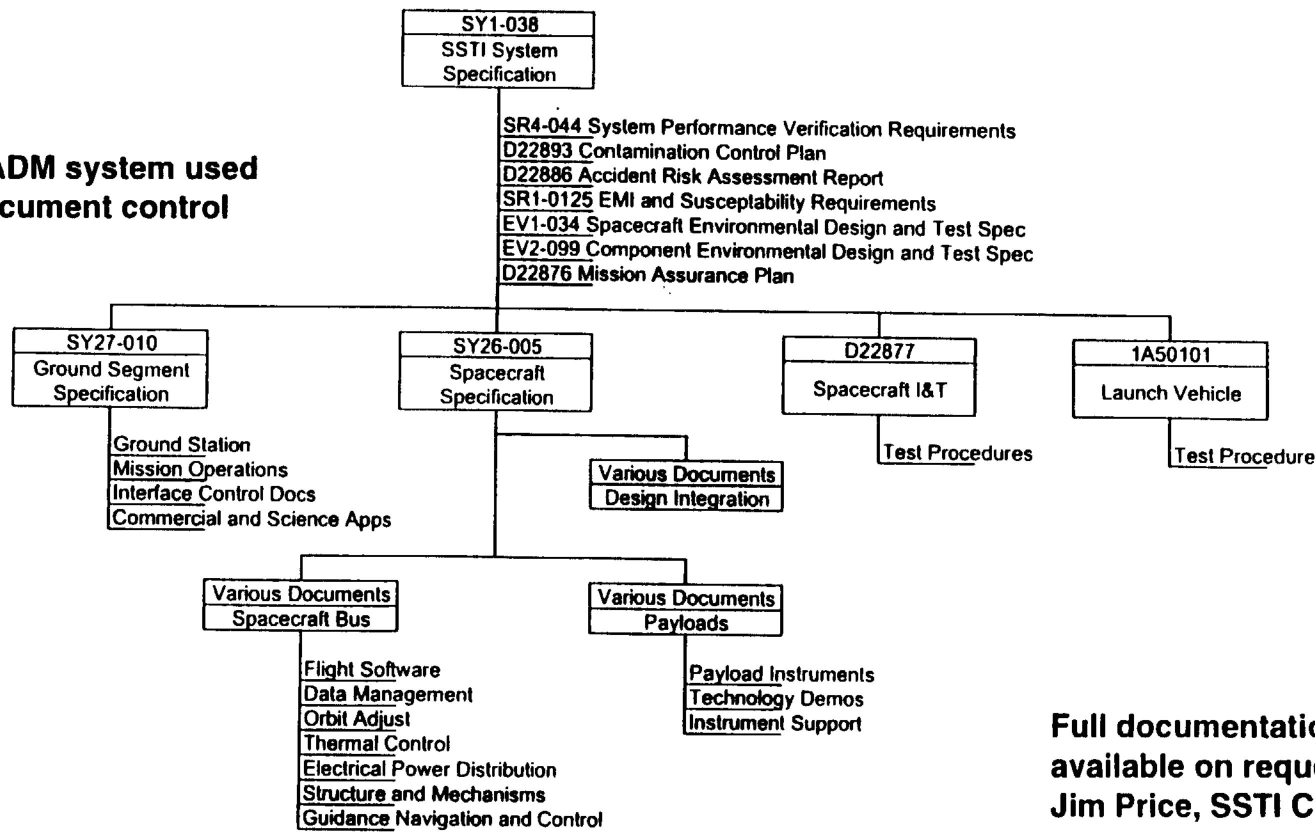
- Derived system performance requirements and operational concepts likewise stable
  - Meet or exceed system requirements
  - No major operational issues

- Key changes driven by 5-year design-to-cost mission goal
  - Additional propellant for drag makeup
  - Selective redundancy (emphasis on 'string' through HSI)
  - Designs revisited for wear-out potential
  - Environmental conditions (both launch & on-orbit)

SSTI System Documentation

- Technical documentation left to contractor judgement
- Intra-program communications is key driver for documentation requirements
- SSTI documents generally tailored from previous programs

TRW CADM system used for document control



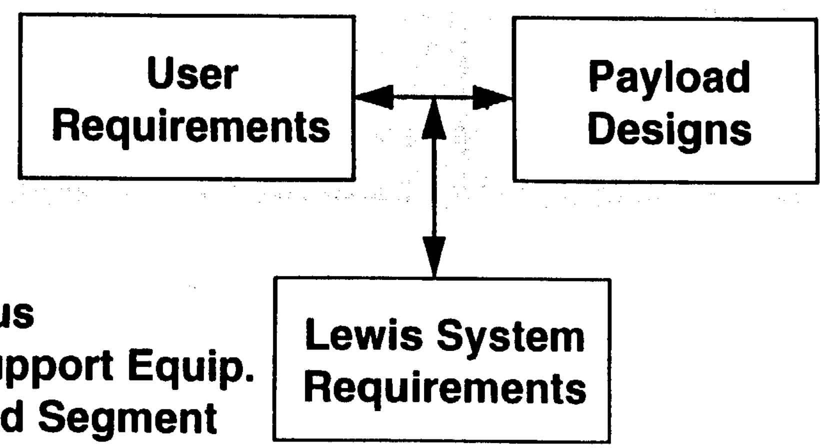
Full documentation tree available on request from Jim Price, SSTI CM

System Documentation Status

Document		Status	Near-Term Milestone
SY1-038	System Specification	Approved and released	N/A
SY26-005	Spacecraft Specification	Approved and released	N/A
SY27-010	Ground Seg Specification	Distributed for signature	Release to CADM by M/E Jan
D22878	Flight Operations Requirements Document	Approved and released	N/A
D22876	Mission Assurance Plan	Approved and released	N/A
SR1-0125	EMI & Susceptibility Requirements	Approved and released	N/A
EV2-099	Component Environmental Design & Test Specification	Distributed for signature (updated for LLV & 5-yr mission)	Release to CADM by M/E Jan
EV1-034	Spacecraft Environmental Design & Test Specification	Draft released at ICDA-2	Release to CADM by M/E Feb
D22893	Contamination Control Plan	Draft released for comments	Draft release M/E December
D22886	Accident Risk Assessment Report	Draft document	Final draft M/E Mar 95
1A50505	Launch Vehicle Interface Control Document	Draft released for comments	Final approval by M/E Jul 95
	Subsytem Specifications	Completed	
SR4-044	System Performance Verification Requirments	Draft document	Release CDA closeout
D22877	S/C System Test Plan	Draft in progress	Draft release M/E Mar 95
	Interface Control Documents	Various states: draft to complete	
	Equipment Specifications	Various states: draft to complete	

Lewis System Performance Requirements Derived from SSTI User Requirements

- End-product requirements established for SSTI-Lewis payloads
  - HSI
  - LEISA
  - UCB
  - Tech Demos



- S/C Bus
- P/L Support Equip.
- Ground Segment

- SSTI requirements development both top down and bottoms up
  - What are the user's "desirements"?
  - What can be supported within SSTI constraints?

- Sufficient degrees of freedom to accommodate both users and developers

SSTI

User-Based Mission Requirements Summary (1 of 3)

TRW

- HSI user requirements are the most stringent and drive system performance requirements
  - Global access and rapid revisits
  - High ground resolution, high spectral resolution
  - Accurate ground position knowledge

- Earth Observation requirements and synergy with HSI are highly suited for LEISA, besides flight qualification for Planetary mission to Pluto
  - Relatively coarse ground resolution (compared to HSI)
  - Less stringent ground position knowledge
  - Look capability ahead for HSI

- Astrophysical Science requirements on UCB observations are unique, but do not drive system performance requirements
  - Inertial, anti-sun pointing in eclipse

SSTI NASA

User-Based Mission Requirements Summary (2 of 4)

TRW

I. Primary Payloads

MISSION PARAMETER	PRIMARY-PAYLOAD USER REQUIREMENTS		
	HSI	LEISA	UCB
Operational Design Life	5 years	3 years	3 years
Global Access / Revisit Period	7 days	HSI acceptable	N/A
Ground Sample Distance (GSD)	≤ 5 m Panchromatic ≤ 30 m Hyperspectral	≤ 300 m	N/A
Max Increase in Off-nadir GSD	15%	per design	N/A
Scene Local Time (nominal)	10:30-11:30 AM	per design	N/A
Swath Width	10 km Panchromatic 5 km Hyperspectral	per design	N/A
Swath Length ('Scene' Definition)	20 km	70 km	N/A
Band Selectivity	yes	no	no
Abs. Grnd-Sample Position Knowledge	≤ 200 m (3-σ)	≤ 1 km (3-σ)	≤ 0.5 deg, sidereal pointing
Boresight Jitter	< 20% IFOV (rms)	per design	not critical
Minimum Daily Mission Data Volume	← 1 Gbit →		
Longest Continuous Data Acq'n Period	30 sec (select bands) (120 sec goal)	50 sec	30 min
Minimum Functional Data Acq'n Frequency	Once per orbit	Once per orbit	Once per orbit
Minimum Data Acq'n Period Required to Satisfy Performance Requirements	3 sec (one full-band scene)	20 sec	15 min
Data Latency (to Stennis Data Center)	< 24 hrs	< 24 hrs	~ week

SSTI NASA

User-Based Mission Requirements Summary (3 of 4)

TRW

MISSION PARAMETER	PRIMARY-PAYLOAD USER REQUIREMENTS (continued)		
	HSI	LEISA	UCB
Spectral Range	0.48 - 0.75 µm Panchromatic 0.40 - 2.50 µm Hyperspectral	1.0 - 2.50 µm	55 - 105 nm
Spectral Resolution	per design (< 10 nm)	per design, $\lambda/250$	0.5 nm
Spectral Co-registration	< 20% of IFOV	per design	N/A
MTF	per design	per design	N/A
Spectral Noise Equiv. Radiance (NER)	see Table below	per design	N/A
Sensitivity goal at 100-hr exposure	N/A	N/A	200 ph/sq.cm/sr/s
Bit Resolution	8 bits Panchromatic 12 bits Hyperspectral	12 bits	N/A
Radiometric Accuracy (Absolute, 1-σ)	< 16 % Panchromatic < 6 % Hyperspectral	per design	N/A
On-Orbit Calibration Drift	< 15 % Panchromatic < 5 % Hyperspectral	per design	per design
Pixel to Pixel Precision (Relative, 1-σ)	< 4 % Panchromatic < 2 % Hyperspectral	per design	N/A

HSI Spectral Noise Equivalent Radiance		
Focal Plane	Wavelength Range	Spectral NER
PAN	0.48 - 0.75 µm	< 0.60 W/sq m/sr
VNIR	0.4 - 1.0 µm	< 1.00 W/sq m/sr
SWIR	0.9 - 1.1 µm	< 0.89 W/sq m/sr
SWIR	1.1 - 1.8 µm	< 0.38 W/sq m/sr
SWIR	1.8 - 2.5 µm	< 0.11 W/sq m/sr

SSTI

User-Based Mission Requirements
Summary (4 of 4)

TRW

II. Independent Technology Demonstrations

- Tech Demos do not drive system performance requirements
  - Require accommodation
  - Structural support, power, electrical I/Fs, thermal control, ...

- SLAM, however, requires operation during launch
  - Data rate and storage requirements less lower than HSI

HSI Payload is Key Driver of System Performance Requirements

- Orbital Conditions
  - Driven by HSI user requirements for weekly global access, 5-meter ground sample distance, and lighting conditions
- On-board data handling
  - Data rate and storage requirements driven by high spectral/spatial resolution and size/number of ground scenes
- Downlink communications
  - Daily HSI data volume drives downlink rates & ground station support
- Guidance, Navigation, and Control
  - Ground-sample position accuracy drives accuracy requirements for pointing and spacecraft position

System Performance Summary
(1 of 3)

Parameter	Requirement	Capability
S/C Operational Orbit		
• Ground target accessibility (HSI and LEISA)	Global	Comply
• Target revisit potential	Weekly	Comply
Altitude (wrt mean eq. rad.)	523 ± 10 km	Comply
Inclination	97.5 ± 0.1 deg (sun sync)	Comply
Time of ascending node	10:50 ± 0:20 AM, local	Comply
Mission Life & Reliability		
• Mission life	5 years (goal)	5 years
• EOL mission reliability	> 0.70 (goal)	0.73 predicted
• EOL S/C bus reliability	> 0.80 (goal)	0.83 predicted
• 3-year S/C bus reliability	> 0.90	0.92 predicted
Communications		
Mission data downlink rate	≥ 2 Mbps, S-band	2.048 Mbps, S-band
• Bit error rate	1 x 10^{-9} compressed data	Comply
	1 x 10^{-6} otherwise	Comply
Min. link margin	3 dB	> 3 dB

• Indicates user-based mission requirement

System Performance Summary
(2 of 3)

Parameter	Requirement	Capability
Data Handling		
• Daily mission data volume	≥ 1 Gbit	~ 2 Gbit at Chantilly G.S. ~ 6 Gbit at Fairbanks G.S.
Max data collection rate	440 Mbps (w/overhead)	~ 440 Mbps
On-board data storage	≥ 2 Gbits	4 Gbits
• Data compression, lossless	≥ 2:1	> 2:1
• Data compression, lossey	> 10:1	Up to ~ 60:1
Data time tag accuracy	≤ 2 ms (3-sigma)	< 2 ms (3-sigma)
• HSI band selectivity	Any combination	Comply
• Max continuous data acquisition period	30 sec (10% tolerance) (Pan mode or 10% H-S lines)	~ 30 sec
• Ground-based mission data processing	Level 1A	Comply

System Performance Summary
(3 of 3)

Parameter	Requirement	Capability
Guidance, Nav. & Control		
• Ground-sample position knowledge	≤ 200 m	< 200 m (TBR *)
S/C position knowledge	≤ 150 m	60 m, filtered 150 m, unfiltered
S/C attitude knowledge	≤ 10/30/50 arc-sec in roll/pitch/yaw	≤ 8/25/30 arc-sec in roll/pitch/yaw
• Ground-sample position control	≤ 450 m, cross-track ≤ 2000 m, in-track	~ 300 m ~ 600 m
S/C position control	± 10 km wrt nominal	Comply
S/C attitude control	≤ 0.04 deg in pitch/roll ≤ 0.50 deg in yaw	≤ 0.02 deg in all axes
• Pointing offsets from nadir	±22 deg in roll ±0.25 deg in pitch ±3.8 deg in yaw	Comply
• Inertial pointing	Point anti-sun to within 0.5 degrees	< 0.2 degrees each axis
General Spacecraft		
• HSI boresight jitter	< 20% IFOV (rms)	TBD (*)

Note: All appropriate values are 3-sigma unless otherwise noted.
(*) Coupled HSI-spacecraft structural analysis in progress; complete prior to HSI CDR.

SSTI

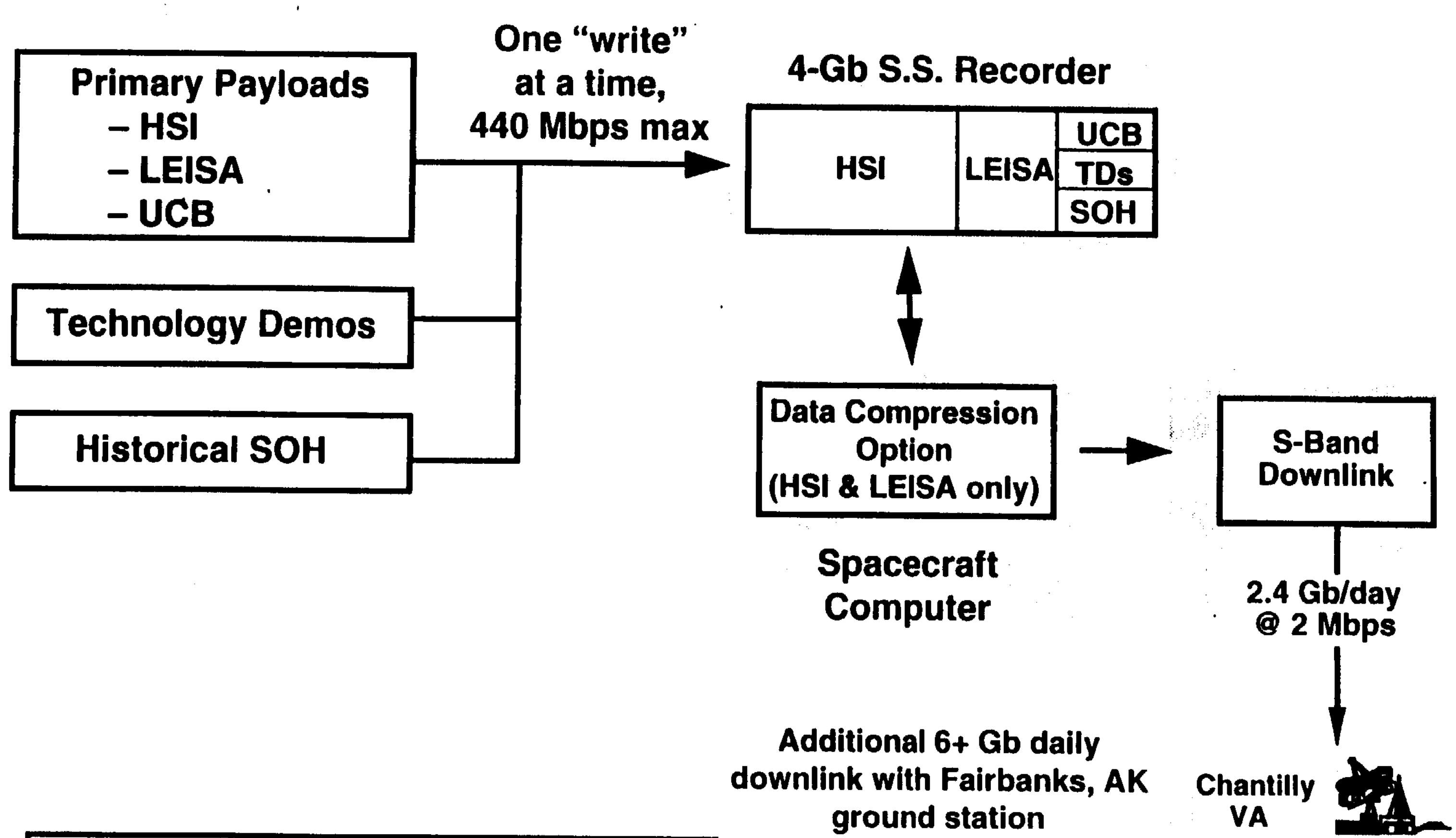
HSI Drives Orbital Conditions

TRW

Orbital Parameter	Value	Trades/Drivers
Nominal Altitude (relative to mean equatorial radius)	523 km (95.1 min period, 34.3 to 35.3 min eclipse)	• Revisit time • Ground coverage & max cross-track pointing angle (22 deg) • Ground resolution vs sensor size, mass, & cost • Drag makeup fuel vs insertion fuel
Altitude Variation	$\pm$ 10 km	• Contiguous swath coverage
Eccentricity	0	• Uniform global coverage
Inclination	Sun-Synch (97.5 deg)	• Repeatable lighting conditions
Ascending Node	10:50 AM $\pm$ 0:20 local time	• Low cloud cover • Favorable lighting conditions

- Conditions acceptable to all other primary payloads and tech demos
- Only additional requirement is inertial, anti-sun pointing mode for UCB

Store-and-Forward Concept for Mission & Historical SOH Data



HSI is key driver for Recorder size

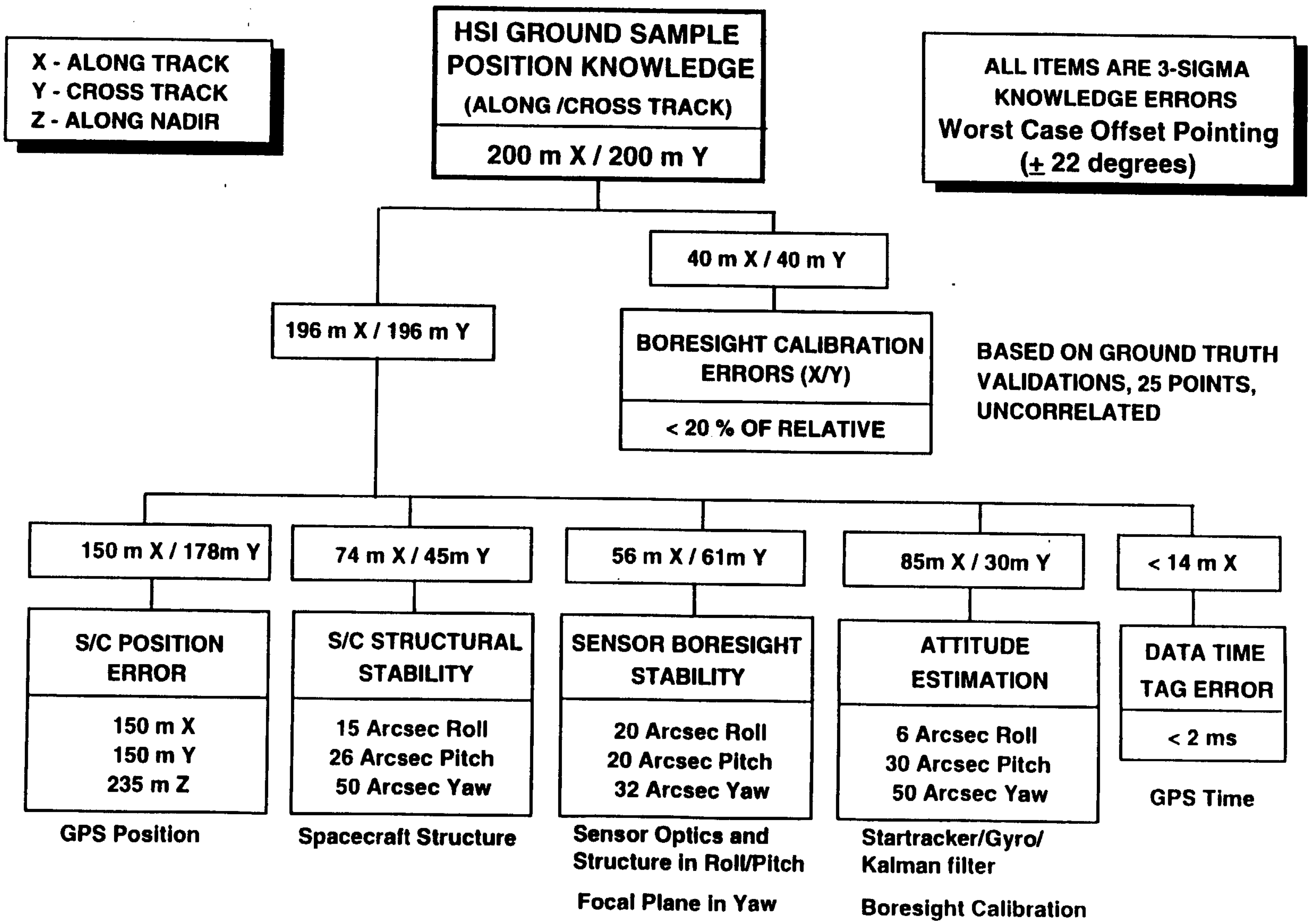
Knowledge Requirements for Spacecraft Pointing, Position & Timing

- Absolute ground-position accuracy requirement for HSI drives knowlege requirements:
  - Spacecraft position
  - Sensor boresight
  - Data time-tagging

- No 'cliff' near 200-m requirement
  - Users often deal with order-of-magnitude larger knowledge errors
  - Ground control points used for image processing

- User desirement to achieve pixel-level knowledge
  - Yields considerable simplification in image processing

Requirements Tree for Ground Position Knowledge

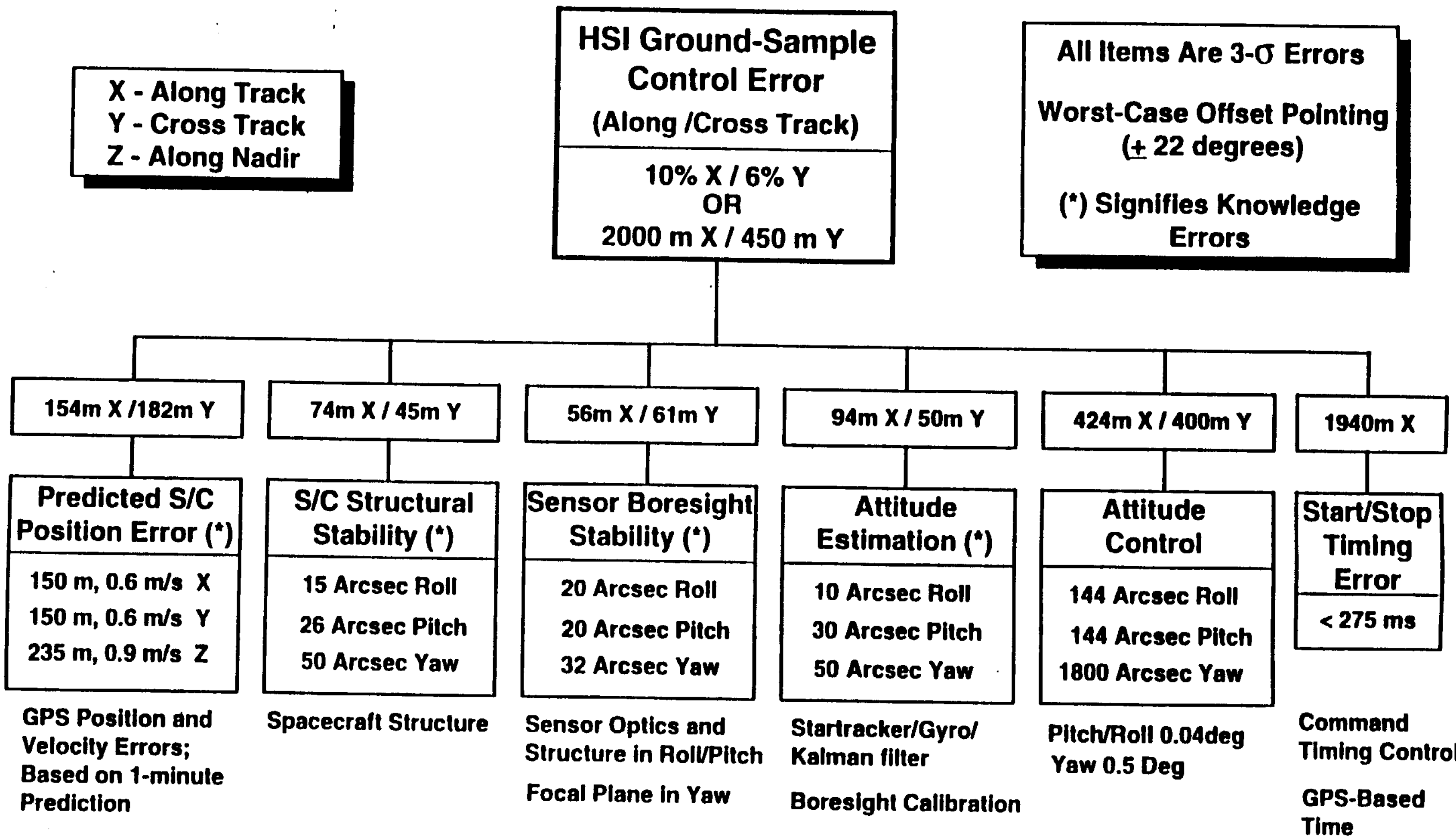


Spacecraft Control Requirements Summary

- HSI user requirement ground-image position control drives control requirements for spacecraft pointing, position, and timing
  - Tolerance "small" compared to scene dimensions (scene definition: 7.7 km wide x 20 km long)
  - Cross-track position tolerance < 6% of swath width
  - In-track position tolerance < 10% of scene length

- Operational approach
  - 5 minutes prior to data acquisition, roll spacecraft to estimated off-nadir position
    - >> Coarse, large-angle maneuver
    - >> Ground-generated stored commands
  - Update roll offset angle and data acquisition start time approximately 1 minute prior to predicted start time
    - >> Fine, small-angle maneuver
    - >> On-board computation

Spacecraft Control Requirements Tree



"Day in the Life" Operational Assessment

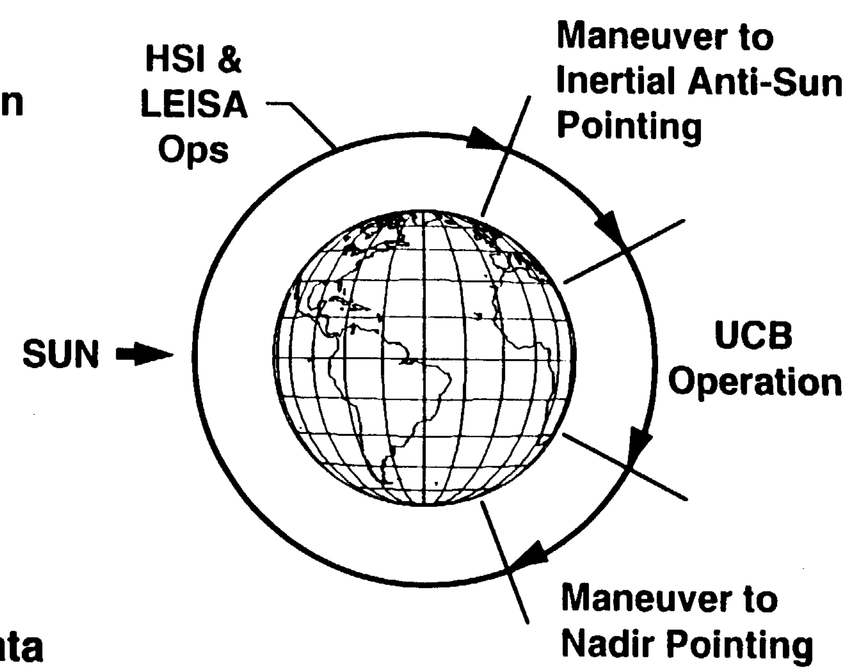
- Day-in-the-Life scenario used to assess on-orbit resource usage
  - Memory
  - Power
  - Time for maneuvers, calibrations, etc
- "Maximal" scenario chosen
  - All primary payloads observing
  - All tech demos running
- Scenario based on:
  - Experimenter operations requirements (ref: SSTI FORD)
  - Spacecraft and ground segment design capabilities
- Resources are adequate to meet experimenter requirements

SSTI

On-Orbit Operations

TRW

- HSI & LEISA operate during daylight
  - HSI: $\pm$ 0-22 deg roll offset from nadir
  - LEISA: 'look ahead' nominal operation using pointing mirror
- UCB operates during eclipse
  - Inertial, anti-sun pointed
- Many windows for Tech Demo operation
  - Background low-rate, low-volume
  - No special maneuvers
- Store and forward concept for mission data and historical telemetry
  - Primary ground station at Chantilly, VA
  - Additional 'bent pipe' ground stations planned at Fairbanks, AK and NASA Stennis, MS



SSTI

Experimenters Operational Requirements Summary

TRW

	Experiment	Scenario	Data Rate
ASCE	Advanced Solar Cell Exp't (GSFC)	Operates 5 minutes/day.	< 1 Mbit/orbit
ASSCFE	Amorphous Silicon Solar Cell Experiment (TRW)	Operates at spacecraft "noon" and "midnight".	< 1 Mbit/orbit
CAFE	Cloud Editing Exp't (Grnd Demo)	N/A -- Ground Demo	0
DCE	Data Compression Exp't	Operates on HSI or LEISA data.	0
EAE	Enhanced ACS Exp't	N/A.	0
GADFLY	GPS Attitude Determination	Always generating data.	16.4 Mbits/orbit
GEM	Goddard Electronics Module	Always generating SOH data.	0
HSI	HyperSpectral Imager	Driven by target visibility.	1.6 Mbit/km/band
LEISA	Linear Etalon Imaging Spectral Array	Driven by target visibility	12 Mbit/km
MMCHS	Metal Matrix Composit Heat Strap	Generates data 1 hour/week.	0.48 kbit/sec
MOCK	Microcosm Orbital Control Kit	On for continuous intervals of 2 months.	< 1 Mbit/orbit
MSRW	Magnetically-Suspended Reaction Wheel	Operation discretionary. Special operation generates data for 5 minutes every 6 months.	< 1 Mbit/orbit
OOSI	On-Orbit System Identification	N/A -- Ground Demo	0
REM	Radiation Environment Meas. Exp't	Transmits data via 1553 once per day for 10 min.	4 Mbit/day
SLAM	Spacecraft Loads & Acoustics Meas.	Gathers data at launch and during orbit transfer (i.e. all other experiments off).	Launch Only
UCB	Ultra-Violet Cosmic Background Spectrometer	Observes each eclipse. Observes beginning 5 min after sunset or SAA exit. Stops observing 5 min before sunrise or SAA entry.	80 Mbits/orbit
WFOVST	Wide Field-of-View Star Tracker	Gathers data 2 orbits / day.	22 Mbits/orbit

Scenario Assumptions

- August 11, 1996 (1st day of nominal operations)
- Primary ground station only (Chantilly, VA)
- Data acquisition during communication events

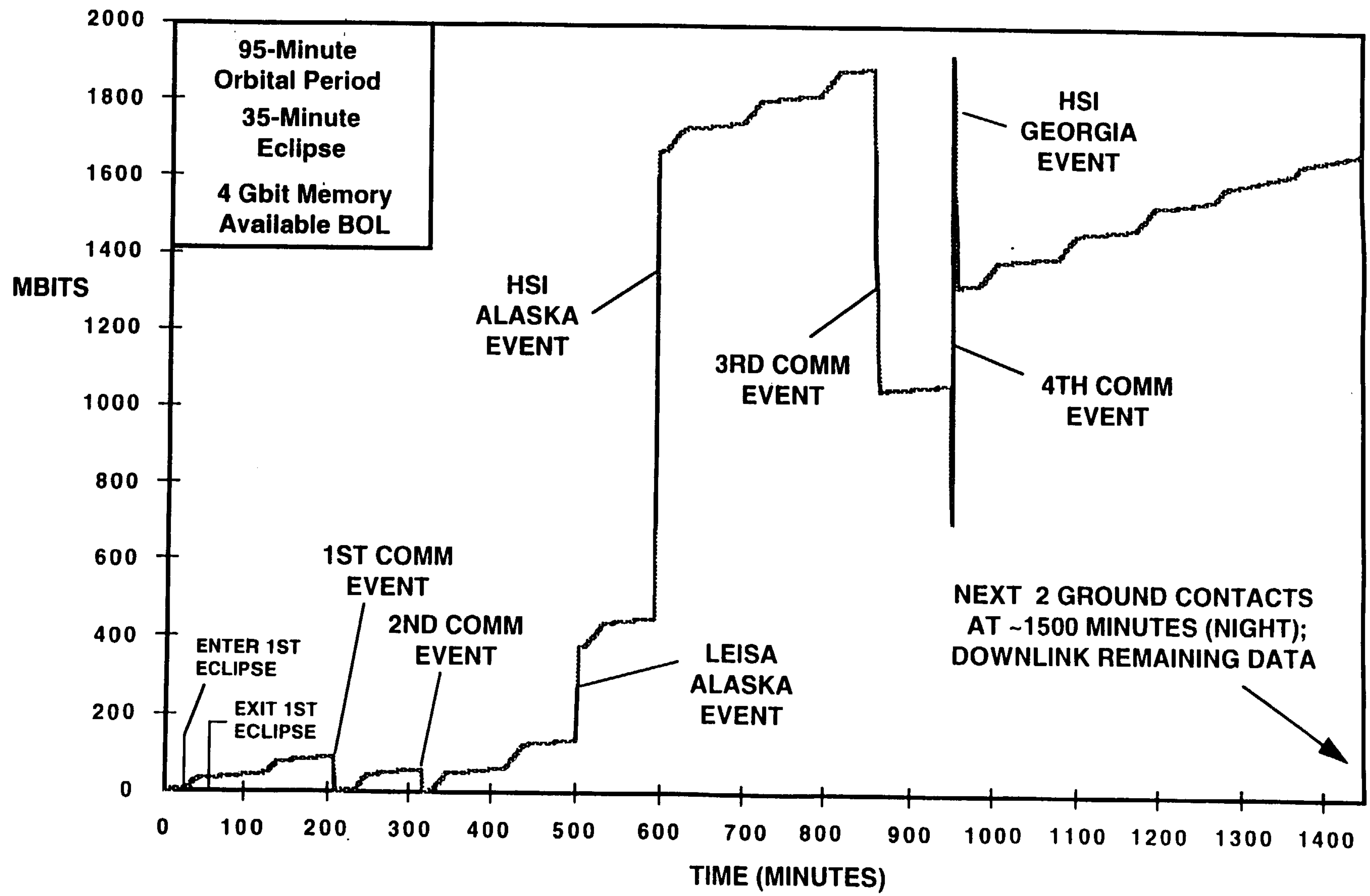
- On-board data compression not employed
- HSI band selection not employed

- HSI observes two sites (Alaska & Georgia) for this scenario
- LEISA observes Alaska target one revolution before HSI
- UCB observes during each eclipse period
- All on-board Tech Demos exercised during 24-hour period according to user requirements

SSTI

Memory Usage History

TRW



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Mission Operations Summary

TRW

- Preliminary assessment indicates no obstacles to fulfilling operational requirements in FORD

- Scenario(s) will be evaluated as resource estimates are refined

- Process and tools in place to evaluate other scenarios
  - Additional ground stations, e.g., Fairbanks, AK
  - Additional HSI and LEISA targets
  - Target revisit characteristics
  - Observation contingencies

Summary of Lewis System Performance Requirements

- User-based mission requirements relatively stable since ATP
- HSI is key driver of system performance requirements
  - Orbital conditions
  - On-board data handling
  - Downlink communications
  - GN&C
- Derived system performance requirements and operational concepts likewise stable
  - Expect to meet or exceed system requirements
  - Detailed analysis of HSI boresight stability in progress (coupled HSI-spacecraft structural analysis to be completed prior to HSI CDR)
  - No major operational issues
- Key changes driven by 5-year design-to-cost mission goal
  - Additional propellant for drag makeup
  - Selective redundancy (emphasis on 'string' through HSI)
  - Designs revisited for wear-out potential (minimal changes)
  - Environmental conditions (launch & on-orbit)

SYSTEM REQUIREMENTS
Verification

E. Belte

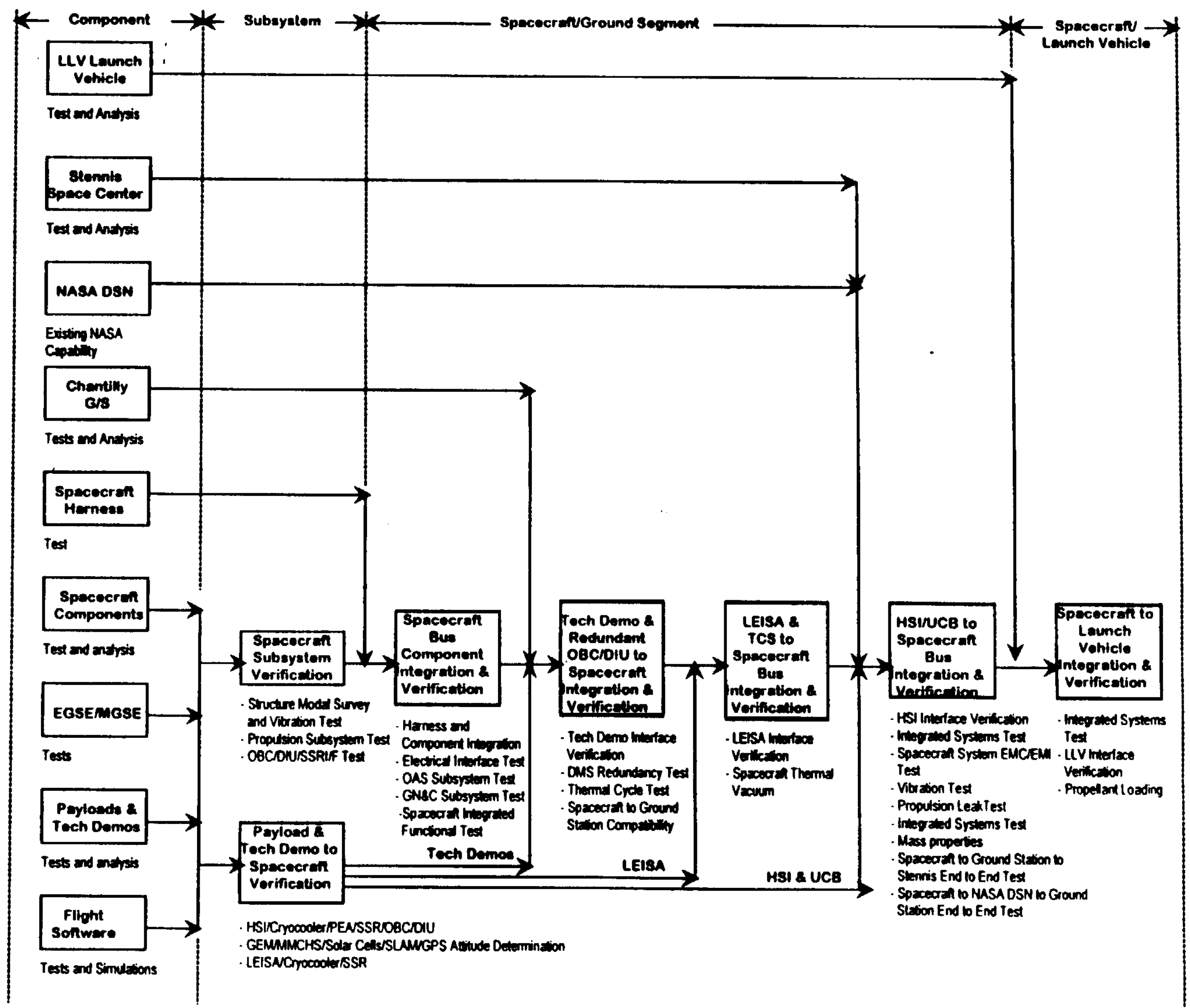
SSTI

Verification Approach

TRW

- Verification of requirements will be accomplished through analysis, simulations and/or test
  - Verification will be performed as low as the part or board level if necessary to verify compliance. Several Examples are:
    - > Flatwise tensile test of solar array substrate
    - > Thermal cycle test of Recorder Interface Module board
    - > Structural analysis of solar array hinge fitting
    - > Propellant Tank pressure proof test
- A building block approach is employed
  - Verification starts at part and component level
  - High Risk subsystems are built up and tested prior to integration with the spacecraft
  - Basic Spacecraft Bus subsystems are integrated and tested
  - Tech Demos and Primary instruments are added and tested on the spacecraft bus
  - Finally the spacecraft is integrated and tested with the Ground System which leads to the final verification of the entire SSTI System

Building Block Verification Approach



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System / Subsystem Requirements Verification Matrix

TRW

- Verification Matricies for specification requirements of major SSTI systems and subsystems will be created
  - The purpose of these matricies is to assure completeness of planned tests and analytical documentation
  - They also provide a roadmap to the location of supporting tests and/or analysis documentation
- Initial versions of these matricies are contained in this review package
- The matricies will be updated as major verification events occur on the program

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System / Subsystem Requirements Verification Matrix

TRW

- **Verification Matricies will be produced for the following systems and Subsystems**

System or Subsystem	Requirements location	Responsible for Preparation
SSTI System	SY1-038	Systems Engineering
Spacecraft	SY26-005	Systems Engineering
Ground Segment	SY27-010	Ground Segment Mgr.
Launch Vehicle	1A50101 (LMSC document)	Launch Segment Mgr.
Software	SS22-013	Software Subsystem Mgr.
DMS	SS12-013	DMS Subsystem Mgr.
TT&C	SY1-038 and SY26-006	TT&C Subsystem Mgr.
OAS	SS3-055	OAS Subsystem Mgr.
TCS	SS13-058	TCS Subsystem Mgr.
EPDS	SS14-024	EPDS Subsystem Mgr.
Structures	SS1-069	Structures Subsystem Mgr.
GN&C	SS7-052	GN&C Subsystem Mgr.
HSI	SS31-003	HSI Payload Mgr.

SSTI

Component / Tech Demo / Instrument Requirements Verification

TRW

- In most cases, verification of requirements will be conducted at the Component (box) or Subassembly level
  - Verification of component level performance is the responsibility of the appropriate Subsystem Engineer
  - Compliance at the component level is demonstrated via a test data package submitted with each component as a deliverable item to TRW
  - In some cases, verification matrices are prepared at the component level at the discretion of the Subsystem Engineer
- Verification of Interface Requirements for Tech Demos and Payload Instruments is the responsibility of the TRW Payload Manager and each of the Experimenters
  - A verification matrix OR test data package which demonstrates compliance with the agreed to requirements set forth in each Interface Control Document is required

SSTI

Component / Spacecraft Environmental Design and Test Verification Requirements

TRW

- EV2-099 governs environmental design and test requirements for all spacecraft components
- EV1-034 controls environmental design and test requirements at the Spacecraft level
- To reduce risk at the spacecraft level, the overall environmental test philosophy is to demonstrate workmanship and performance at the component level first and then at the spacecraft level
  - Component test levels will be greater than or equal to levels experienced at the spacecraft level or in flight
- Acceptance level testing used on all "build to print" components
- Protoflight levels used on all other components
- Spacecraft tests will be performed at the acceptance level

Summary of SSTI Environmental Verification Tests

Test Type	Component Level	Spacecraft Level
Temp Cycle Thermal Vacuum	8 temperature cycles in vacuum or ambient required	Minimum of 8 Thermal Cycles. Minimum of 4 Thermal Vacuum Cycles
Vibration	1 minute per axis in all three axes	1 minute per axis in all three axes. Levels will incorporate launch vehicle vibration and acoustic effects
Acoustic	Performed only on completed solar array assemblies	None required - Vibration serves as acceptance test
Pyroshock	None required	Induce L/V pyrotechnic shock Fire all S/C energy release devices one time
Static Load	Required on all composite or bonded load bearing structures	None required
Pressure/Leak	Propulsion subsystem, Cryocooler, heat pipes	Propulsion subsystem leak check
EMI/EMC	Required on selected components	Generated Interference and Susceptibility

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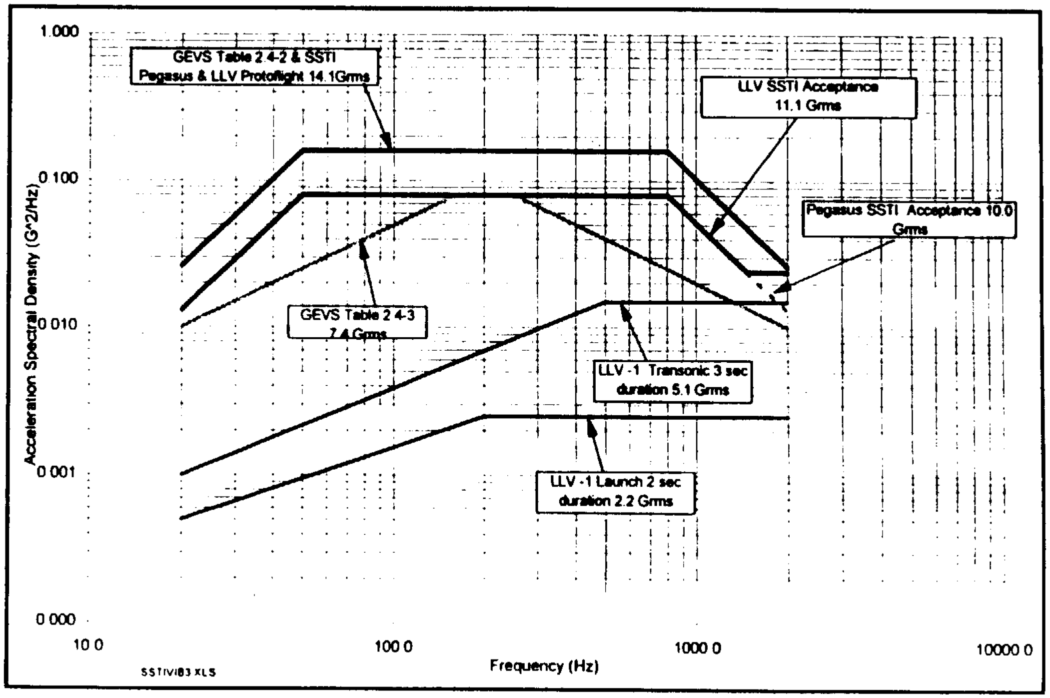
Environments
Vibration

TRW

- Component Protoflight levels at 14.14 Grms
- Component Acceptance levels at 10.26 Grms (was 10.1 for Pegasus)
- Spacecraft Acceptance test will be conducted at Launch Vehicle induced environment as the result of random vibration and acoustic induced environments
  - Specific curve shape to be determined



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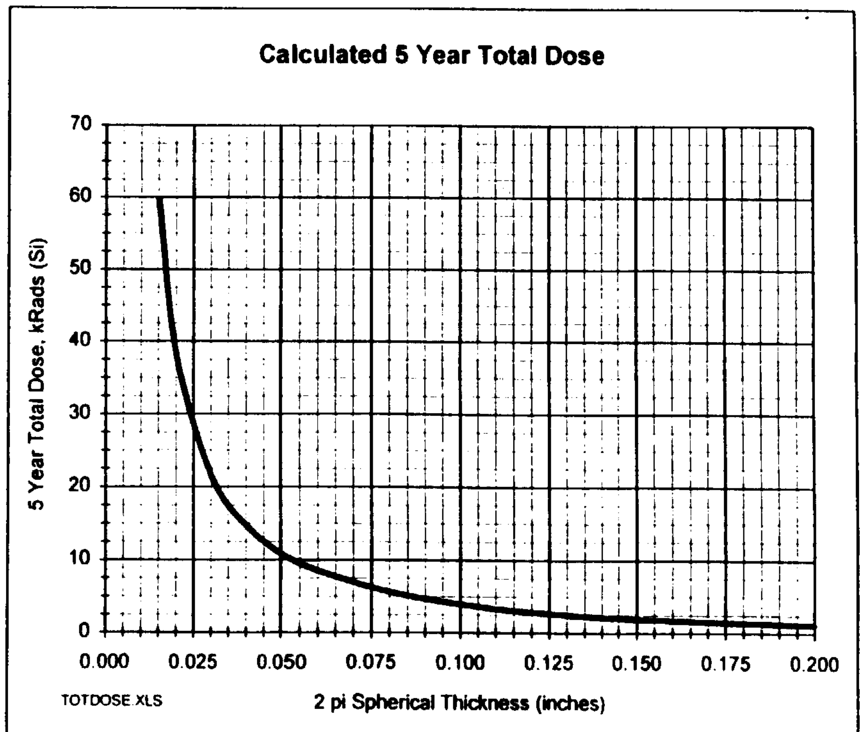
Environments
EMI/EMC

- EMI/EMC tests will be performed on the following components:
  - On-Board Computer
  - Solid State Recorder
  - Payload Electronics Assembly with Magnetically Suspended Reaction Wheel, Optical Pointing Assembly and Cryocooler attached
  - Wide Field of View Star Tracker
  - Goddard Electronics Module
  - GPS Attitude Determiniation Experiment
  - HSI
  - LEISA
  - UCB
- Component tests may be waived if analytical results show that EMISMs are greater than 20dB
- Spacecraft level tests include:
  - Radiated E and H field spacecraft self generated interference environment
  - Demonstrate 6 dB compatibility margin with respect to launch vehicle and launch site requirements

Environments
Total Dose Radiation

- 5 year calculation using 2pi model with 0.060 inch thick aluminum hemisphere and 2 anomalously large solar flares yields 8.5 Krads
- EV2-099 recommends an uncertainty factor of 2.0 at the piece part level , bringing total dose to 17 Krads
  - For comparison, TOMS total dose levels were 14 Krads for 3 years using a similar radiation model



- See Appendix A for System Specification Requirements Vertification Matrix
- See Appendix B for Spacecraft Specification Requirements Verification Matrix

SSTI

TRW

SYSTEM REQUIREMENTS
Mission Assurance

L. Niemela

SSTI

INTRODUCTION AND SCOPE

TRW

- Multidisciplined Program
  - Reliability
  - Configuration management
  - Safety
  - Hardware & Software Quality Assurance
  - PM&P Control
  - Contamination Control and
  - Performance Verification

SSTI

GOALS

TRW

- Mission success
- On orbit, know exactly what is on the spacecraft
- Capability to trace history of components, parts
- Meet performance objectives at minimum cost
- Demonstrate designs meet SSTI requirements

APPROACH

- Our approach to mission assurance is to define specific product quality criteria early in the program utilizing existing policies and procedures to the extent possible with emphasis on individual responsibility for quality of work

- The mission assurance program best categorized as Class B risk level using best commercial practice for manufacture and assembly

- The mission assurance plan reflects a tailored application of NHB5300.4 (1B) and TRW's Hardware Quality Assurance Manual (HQAM), as supplemented by Quality Directives (QD's) containing how-to procedural instructions by work center

- The plan draws heavily on Space Test Experiments Platform (STEP) experience

SSTI

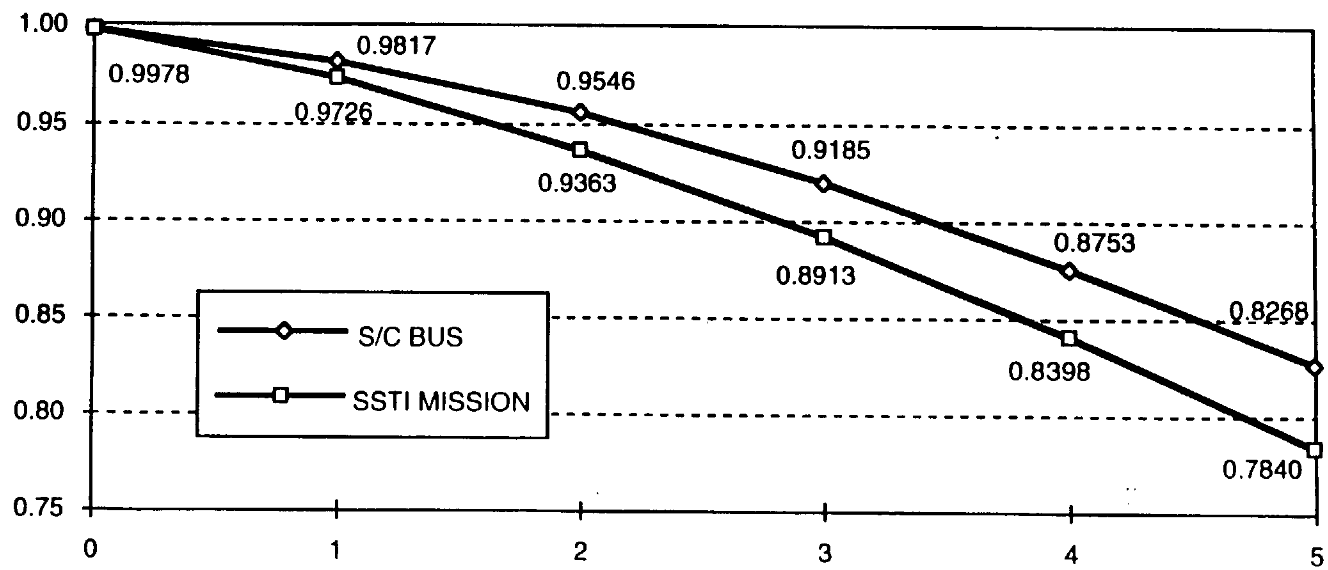
RELIABILITY

TRW

- SSTI Reliability Requirement (from TRW Proposal)
  - SSTI Bus Reliability = 0.90 @ 3 years
- Current Predictions (Estimates)
  - SSTI Bus Reliability = 0.92 @ 3 years
- Recent direction from NASA specifies for TRW to extend the life of the SSTI Mission to 5 years as a goal
  - Current 5-year SSTI Mission reliability prediction is 0.78*
  - Current 5-year spacecraft bus reliability prediction is 0.83
  - Working HSI and spacecraft bus designs to increase reliability within ECP budgetary constraints
- Reliability analyses documented in D22890 <u>Reliability Allocations & Predictions</u>
- Report also includes
  - Reliability block diagrams
  - Reliability predictions and allocations to component/unit level
  - Functional FMEA to component level

** Mission reliability defined as spacecraft bus + HSI + HSI payload support*

SSTI RELIABILITY PREDICTIONS



FMECA SUMMARY

- o ANALYSIS DONE TO COMPONENT LEVEL
- o for ALL MISSION PHASES
- o CRITICALITY: CATASTROPHIC...CRITICAL...SIGNIFICANT...MINOR and, LOSS OF REDUNDANCY
- o MOST ARE LOSS OF REDUNDANCY
- o SINGLE-STRING ITEMS ARE TYPICAL

COMPONENT	FAILURE	COMMENT
SOLAR ARRAY DRIVE	BEARING SEIZURE	CAN STILL OPERATE DEGRADED
S-BAND ANTENNA	CONNECTOR SHORT	VERY LOW PROB
DIU	WDT FAILURE	GROUND COMMAND TO SWITCH OBCs
PCU MAIN BUS	SHORT TO GROUND	LOW PROB...CRITICAL ITEM CONTROL
SAR	RELAY K1 OPEN WIPER	LOSS 1/2 POWER CRITICAL ITEM CNTRL
PROPELLANT TANK	RUPTURE	DESIGN MARGINS

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SSTI SYSTEM SAFETY

- Focus right off on functionally important tasks; no program specific system safety plan
- Accident Risk Assessment Report (ARAR) will be generated to identify potential hazards associated with system design, testing, and handling operations
- Mitigating risk caused by these hazards will be addressed in detailed launch site procedures
- Spacecraft design and launch site operations must comply with the requirements outlined in WRR 127-1, Western Range Regulation
  - "Western Regulation, Range Safety Requirements", 30th Space Wing, 30 June 93
- System Safety Manager will be responsible for all safety issues
  - He will prepare for and participate in range safety reviews
- The TRW System Safety Manual will be used as a reference

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QUALITY ASSURANCE REQUIREMENTS FLOWDOWN

Subcontractors/Suppliers	Statement of Work (SOW) Product Assurance Requirement (PAR) Quality “Q” Clauses
TRW In-House	Quality Project Requirements (QPR) Quality Planning Inspection Instruction (QPII)
Workmanship	MIL Specs, Process Requirement Specification, Engineering Drawing, Equipment Specification, and Manufacturing work instructions
Testing	Test Procedures

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EEE PARTS CONTROL REQUIREMENTS

- Use "Cumulatively Approved" Project Parts List
  - Standard parts selection criteria
  - Design engineer selection
  - QA Review
  - (No formal Project Approved Parts List (PAPL))

- Parts program will be managed by Quality Assurance with on-call assistance from an experienced PM&P Engineer

- Subcontractors of flight hardware will submit EEE parts list to TRW for review and approval

- Screening, and Destructive Physical Analyses (DPA) when appropriate, will be performed on EEE parts by supplier, not as a standard procedure TRW for acceptance

- Parts issues and alerts will be managed and dispositioned using existing TRW management system

SSTI

MATERIAL AND PROCESSES CONTROL

TRW

- Utilize streamlined PM&P Program
- Materials and process will be handled in accordance with established TRW and subcontractor control procedures
- The PM&P control program will operate similar to the EEE parts program
- TRW responsible Design Engineers are responsible for materials and processes selected for use in spacecraft components and assemblies
- Rely on testing; full traceability is not required

SSTI

CONFIGURATION MANAGEMENT

- Systems Engineering and Integration Team (SEIT) has the responsibility for systems configuration
- Flight hardware will be manufactured to documentation released thru TRW Configuration And Data Management (CADM)
- Changes can be incorporated using urgent, Engineering Orders or In-Process Engineering Change Requests per QD.STD.1404
- Configuration Control Board is chaired by SEIT
- Subcontractor delivered items configuration will be defined in deliverable data package, verified by QA in receiving inspection

Product Assurance

- QPR 25164
- Document Control
- Inspection
- MRB
- OAS Subcontracts

Product Assurance
QPR 25164

- QPR 25164 implements the SSTI Mission Assurance requirements
- QPR jointly developed with Mfg., Engineering, Material and QA
- Traditional Quality Assurance tasks shared to encourage ownership of hardware quality by all performers

Product Assurance
Document Control

Document	Control Requirements
Engineering Drawings Acceptance Test Procedures	CADM or Project release and control
MSOs	Generated and approved by Mfg and QA
Tooling and Special Test Equipment	Drawings approved by Mfg. Tooling inspected and accepted by QA, Test Equipment calibrated
Deliverable Data Package	Generated by Mfg. Approved by Engineering, QA and Mfg when applicable

SSTI

Product Assurance Inspection

TRW

- Alternate approach used for receiving inspection
  - Materiel Control personnel authorized to receive and perform V&ID inspection.
  - Reduction of time from dock to on-line anticipated
- Inspection reduced to critical characteristics or operations where possible
- Manufacturing two party verification used as alternate to QA inspection
- Final acceptance of all hardware performed by QA

SSTI

Product Assurance
MRB

- Insitu MRB to be used to extent possible

- The QUIPS Simplified Tracking system (STS) shall be employed
  - New Discrepancy form proposed to allow faster disposition process
  - All in-process discrepancies will be summarized by QA into QUIPS for project discrepancy history
  - Procurment discrepancies will be documented and processed per PDR or SIR instructions

- MRB list D01159-158 will be generated and maintained

SSTI

Product Assurance
OAS Subcontracts

Subcontractor	Component	Quality Requirements
ECC	Latching Valve	DSP Par 700-216/1P added to existing DSP order
Wright	Propellant Thruster Valve	TOMS PAR 700-398. no cost savings using PAR 700-417
SCI	Propellant tank	Q-clauses
Tayco	Catalyst Bed Heaters	Contract in development Par 700-417 (Standard Propulsion Par) proposed

Science and Commercial Applications

Overview	J Pearlman
Mission Data Management System	K Witcher
Education	M Woods
Applications Development	J Pearlman
Data Policy	M Watkins

SCIENCE & COMMERCIAL APPLICATIONS
Overview

J. Pearlman

Applications Program Overview

Demonstrate Scientific and Commercial Viability of HSI+

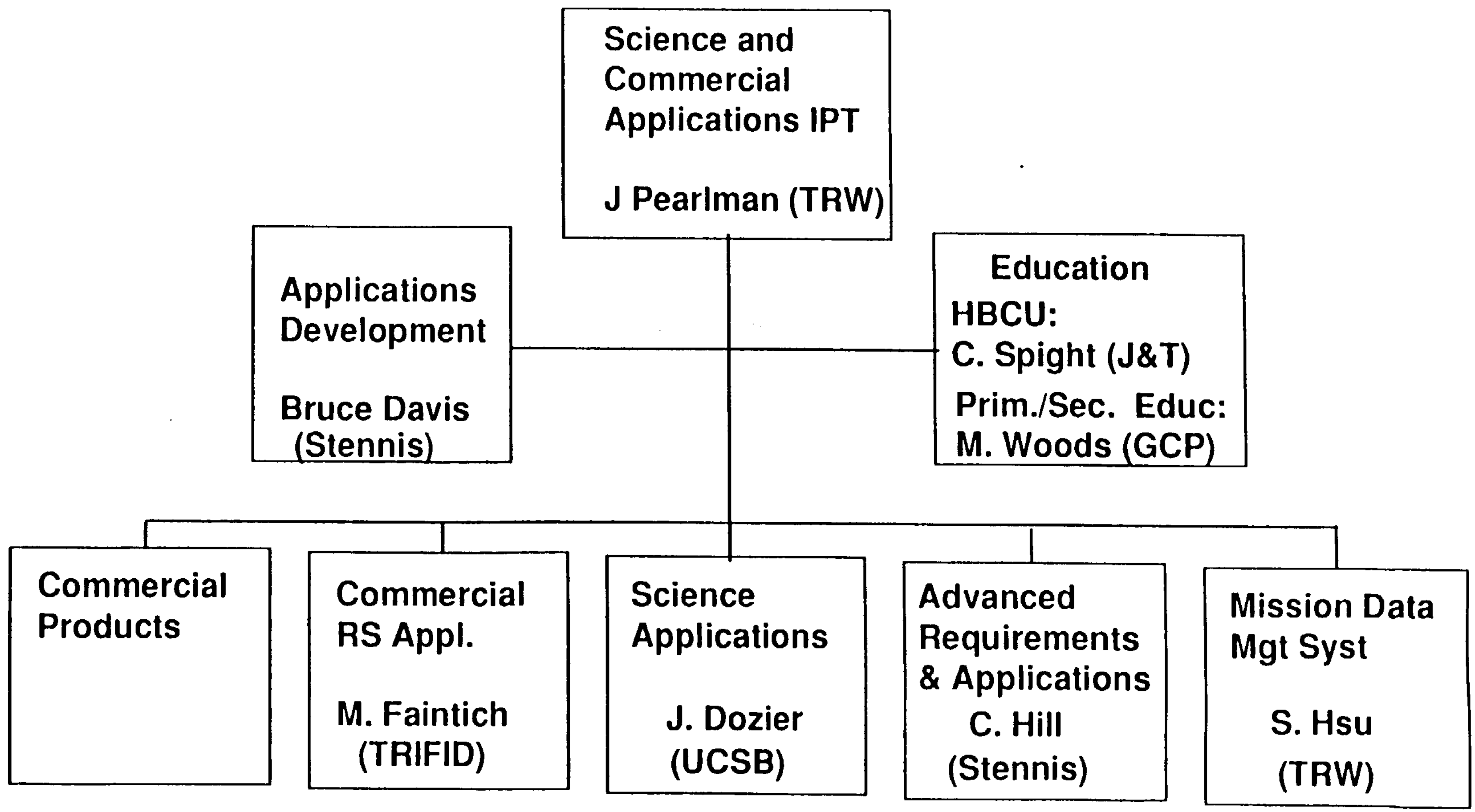
- Assess User Requirements
- Support Focused Applications Demonstrations
- Develop Business and Market Analyses

Provide SSTI User Interface, Data Archiving and Processing For All Payloads

- Satellite User Tasking Priorities
- User Training and Support
- Dial-Up Real-Time Access
- Automated, Quality Data Processing
- Support NASA Data Policy

Establish Education Programs to Train Future Users

Science and Commercial Applications IPT Organization



User-Based Mission Requirements
Summary (1 of 3)

- HSI user requirements are the most stringent and drive system performance requirements
  - Global access and rapid revisits
  - High ground resolution, high spectral resolution
  - Accurate ground position knowledge
- Earth Observation requirements and synergy with HSI are highly suited for LEISA, besides flight qualification for Planetary mission to Pluto
  - Relatively coarse ground resolution (compared to HSI)
  - Less stringent ground position knowledge
  - Look capability ahead for HSI ?
- Astrophysical Science requirements on UCB observations are unique, but do not drive system performance requirements
  - Inertial, anti-sun pointing in eclipse

User-Based Mission Requirements Summary (2 of 3)

I. Primary Payloads

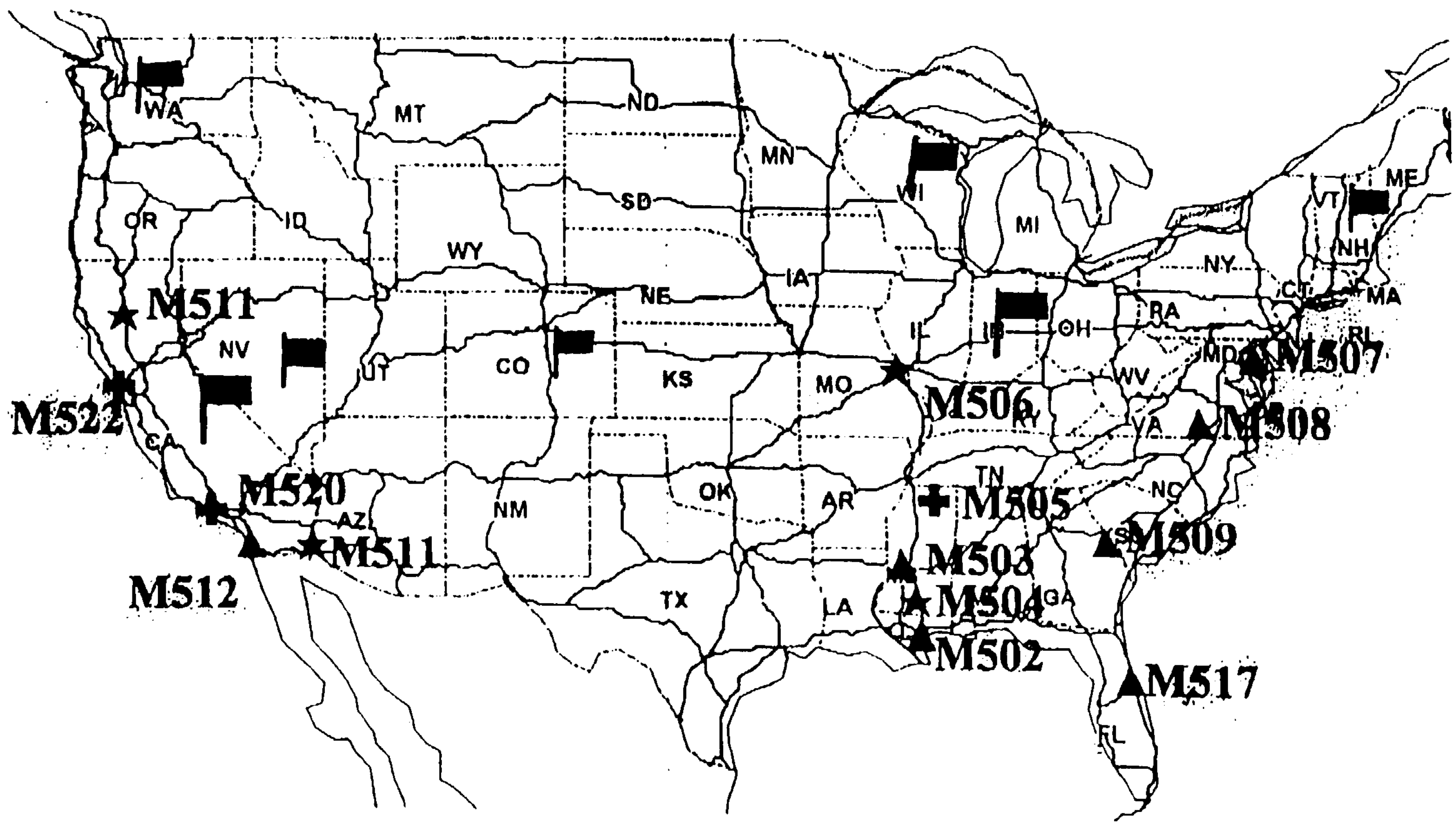
MISSION PARAMETER	PRIMARY-PAYLOAD USER REQUIREMENTS		
	HSI	LEISA	UCB
Operational Design Life	5 years	3 years	3 years
Global Access / Revisit Period	7 days	HSI acceptable	N/A
Ground Sample Distance (GSD)	≤ 5 m Panchromatic ≤ 30 m Hyperspectral	≤ 300 m	N/A
Max Increase in Off-nadir GSD	15%	per design	N/A
Scene Local Time (nominal)	10:30-11:30 AM	per design	N/A
Swath Width	10 km Panchromatic 5 km Hyperspectral	per design	N/A
Swath Length ('Scene' Definition)	20 km	70 km	N/A
Band Selectivity	yes	no	no
Abs. Grnd-Sample Position Knowledge	≤ 200 m (3-σ)	≤ 1 km (3-σ)	≤ 0.5 deg, sidereal pointing
Boresight Jitter	< 20% IFOV (rms)	per design	not critical
Minimum Daily Mission Data Volume	← 1 Gbit →		
Longest Continuous Data Acq'n Period	30 sec (select bands) (120 sec goal)	50 sec	30 min
Minimum Functional Data Acq'n Frequency	Once per orbit	Once per orbit	Once per orbit
Minimum Data Acq'n Period Required to Satisfy Performance Requirements	3 sec (one full-band scene)	20 sec	15 min
Data Latency (to Stennis Data Center)	< 24 hrs	< 24 hrs	~ week

User-Based Mission Requirements Summary (3 of 3)

MISSION PARAMETER	PRIMARY-PAYLOAD USER REQUIREMENTS (continued)		
	HSI	LEISA	UCB
Spectral Range	0.48 - 0.75 μm Panchromatic 0.40 - 2.50 μm Hyperspectral	1.0 - 2.50 μm	55 - 105 nm
Spectral Resolution	per design (< 10 nm)	per design, λ/250	0.5 nm
Spectral Co-registration	< 20% of IFOV	per design	N/A
MTF	per design	per design	N/A
Spectral Noise Equiv. Radiance (NER)	see Table below	per design	N/A
Sensitivity goal at 100-hr exposure	N/A	N/A	200 ph/sq.cm/sr/s
Bit Resolution	8 bits Panchromatic 12 bits Hyperspectral	12 bits	N/A
Radiometric Accuracy (Absolute, 1-σ)	< 16 % Panchromatic < 6 % Hyperspectral	per design	N/A
On-Orbit Calibration Drift	< 15 % Panchromatic < 5 % Hyperspectral	per design	per design
Pixel to Pixel Precision (Relative, 1-σ)	< 4 % Panchromatic < 2 % Hyperspectral	per design	N/A

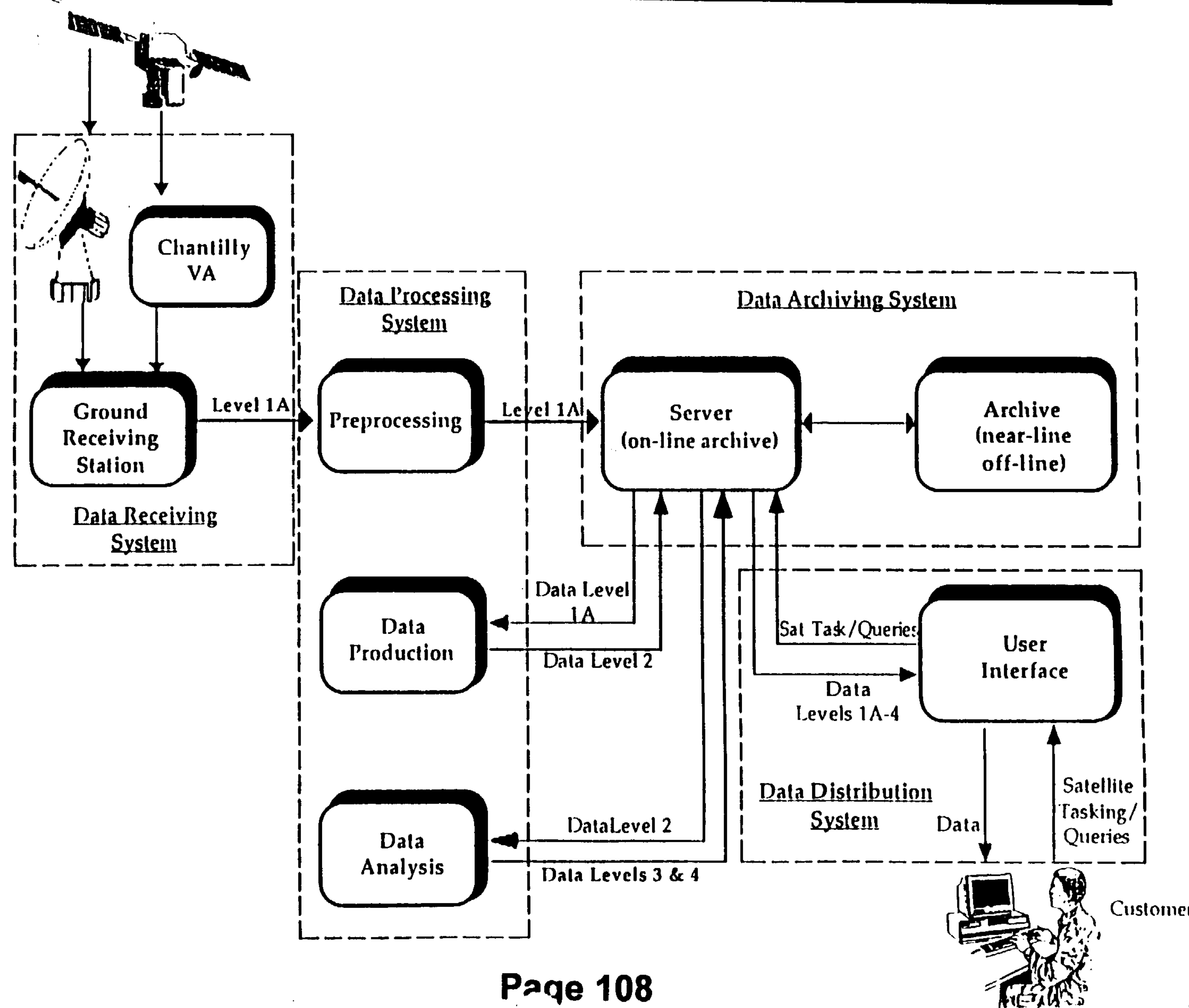
HSI Spectral Noise Equivalent Radiance		
Focal Plane	Wavelength Range	Spectral NER
PAN	0.48 - 0.75 μm	< 0.60 W/sq m/sr
VNIR	0.4 - 1.0 μm	< 1.00 W/sq m/sr
SWIR	0.9 - 1.1 μm	< 0.89 W/sq m/sr
SWIR	1.1 - 1.8 μm	< 0.38 W/sq m/sr
SWIR	1.8 - 2.5 μm	< 0.11 W/sq m/sr

User Applications Overview



▲science ★ commercial ✚education

DATA MANAGEMENT SYSTEM OVERVIEW



Data Policy and Tasking

Applications IPT review proposed the following policy:

- During first ops year, data will be given to teammates; in second and following years until a commercial source is available, archived data will be provided to all US organizations. Thereafter, a restrictive data distribution policy will be initiated(TBD)
- Tasking priorities will follow NASA HQ guidelines with clarifications, if necessary, referred to the SSTI NASA PM.
- During the first year of operations, TRW teammates will have direct tasking access to the SSTP Lewis Tasking Team(LTT); in following years, tasking requests to the LTT will be through working groups: science/university, education, government and commercial working groups.
- Tasking will be run by the SSTP Lewis Tasking Team consisting of the Level 2 Applications IPT managers, a representative from SOCC, a representative from Nasa Hq and chaired by the Lewis Applications IPT manager.

The above policy is under review by Nasa and at TRW; reviews will occur during January and February.

Science and Commercial Applications - Status

User Development

- Phase 1 data acquisitions 50% complete
- User training started in December, 1994; facility funding?
- Applications testing planned for the winter/spring, 1995

Mission Data Management System

- Functional Requirements Document Complete
- Prototype Archive Testbed operational in December, 1994
- Archive Hardware ordered; system testing in Spring 1995

Education

- Schools selected and student training has been initiated
- Student/school projects selected and underway

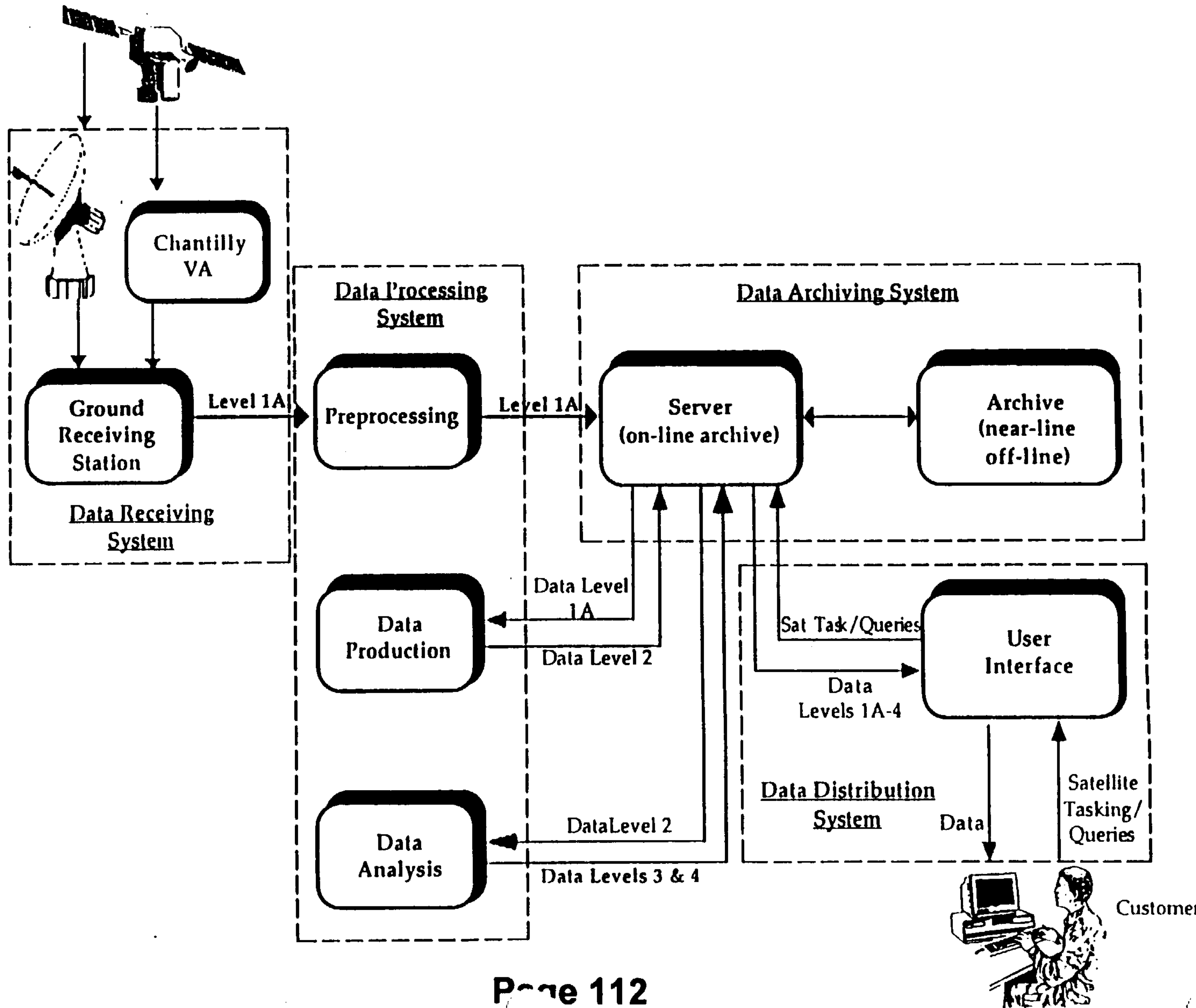
SCIENCE & COMMERCIAL APPLICATIONS
Mission Data Management System

K. Witcher

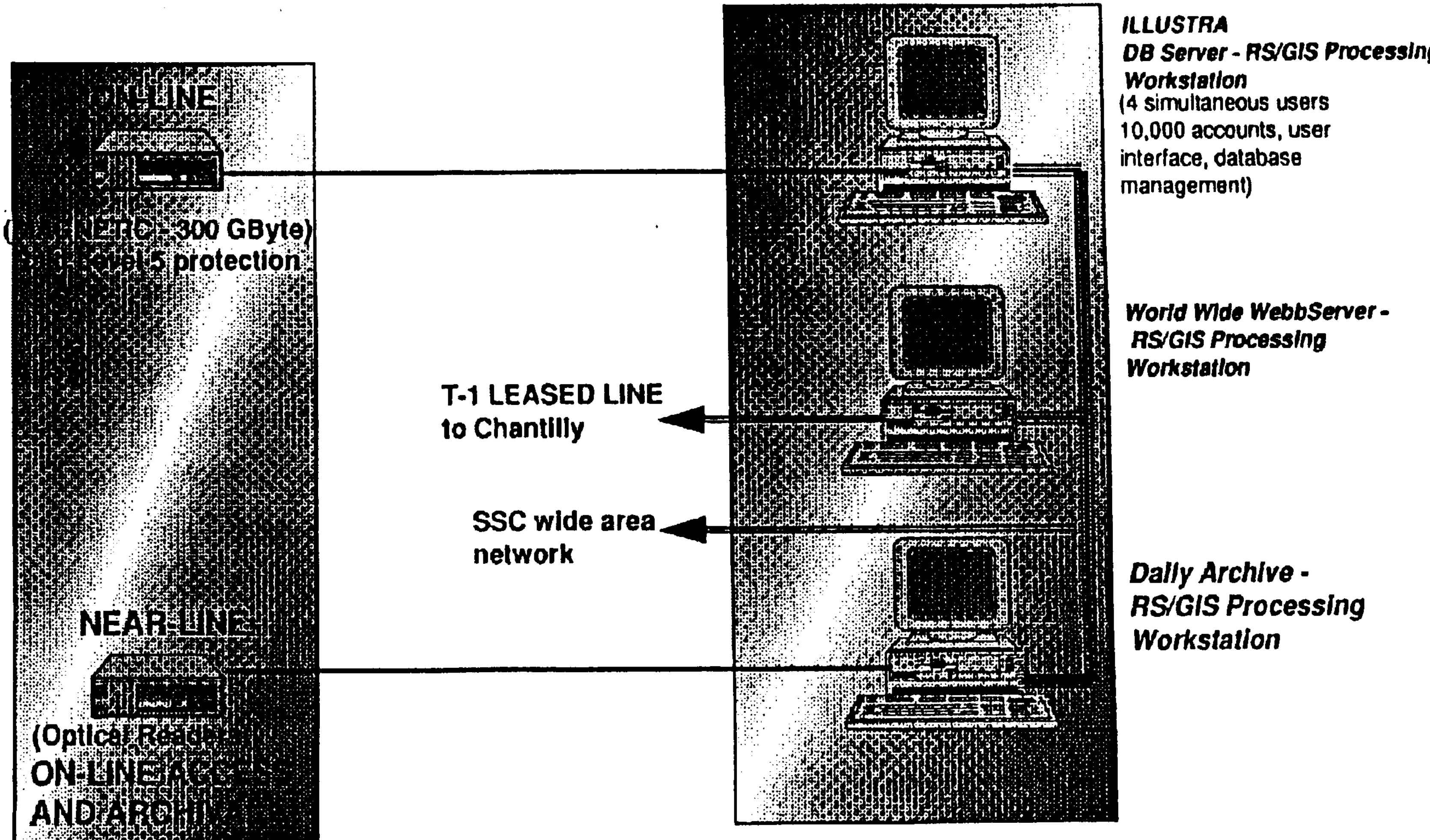
SSTI

DATA MANAGEMENT SYSTEM OVERVIEW

TRW



Data Archive System
Current Configuration



Workstations are 100 MHz - 4 processor Pentiums running Windows NT

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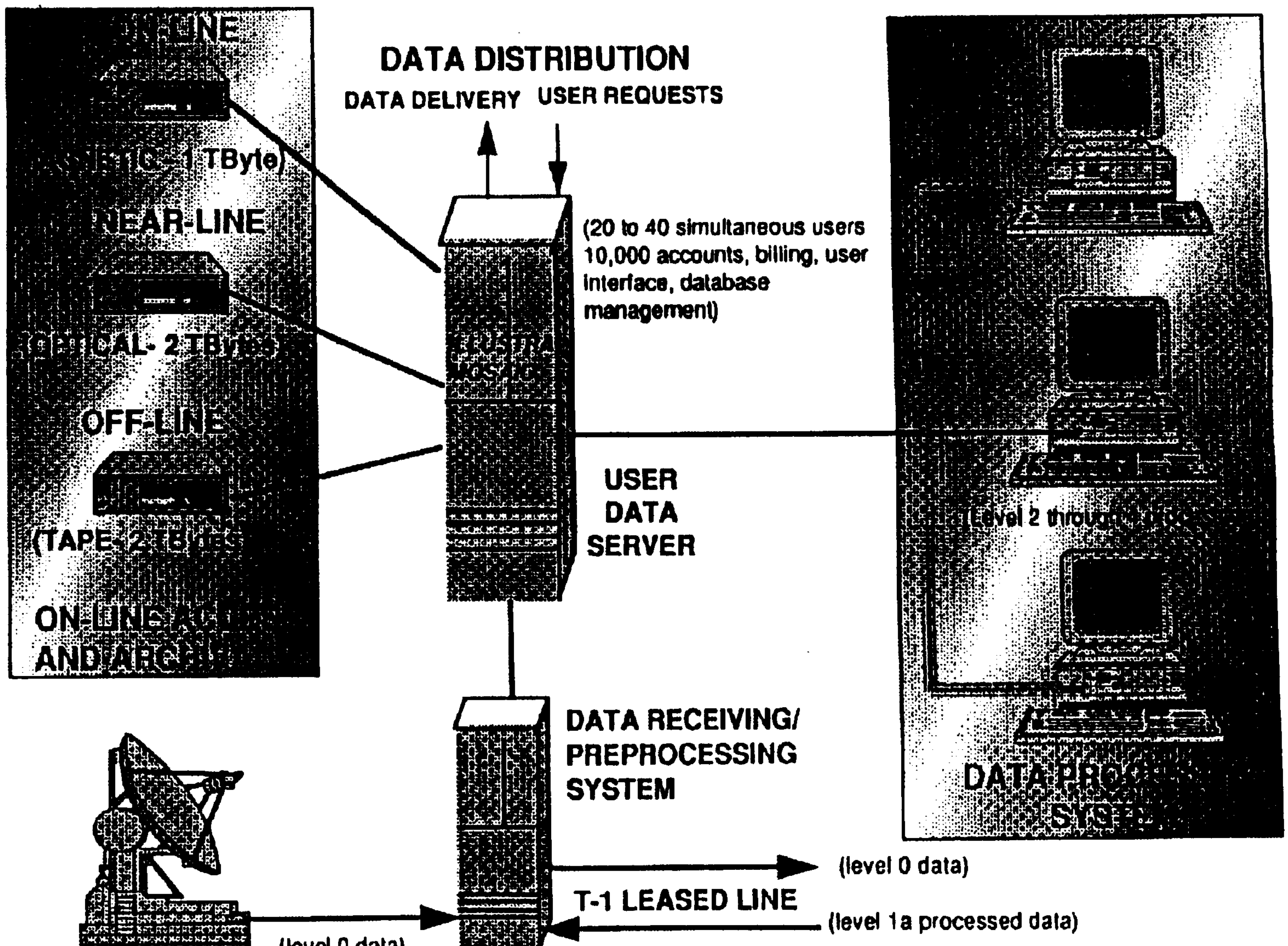
Data Archival System
Future Configuration



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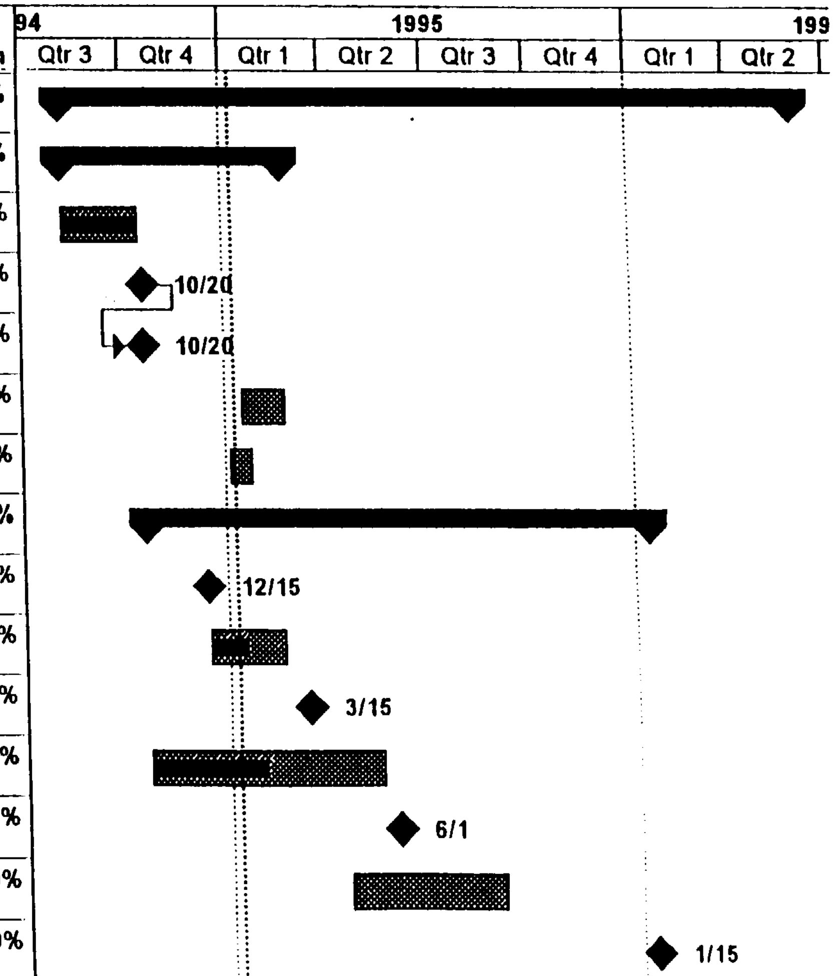
Archive Development Schedule

Archive Requirements have been set and Prototype Demonstration is Underway with Beta Testing at TRW

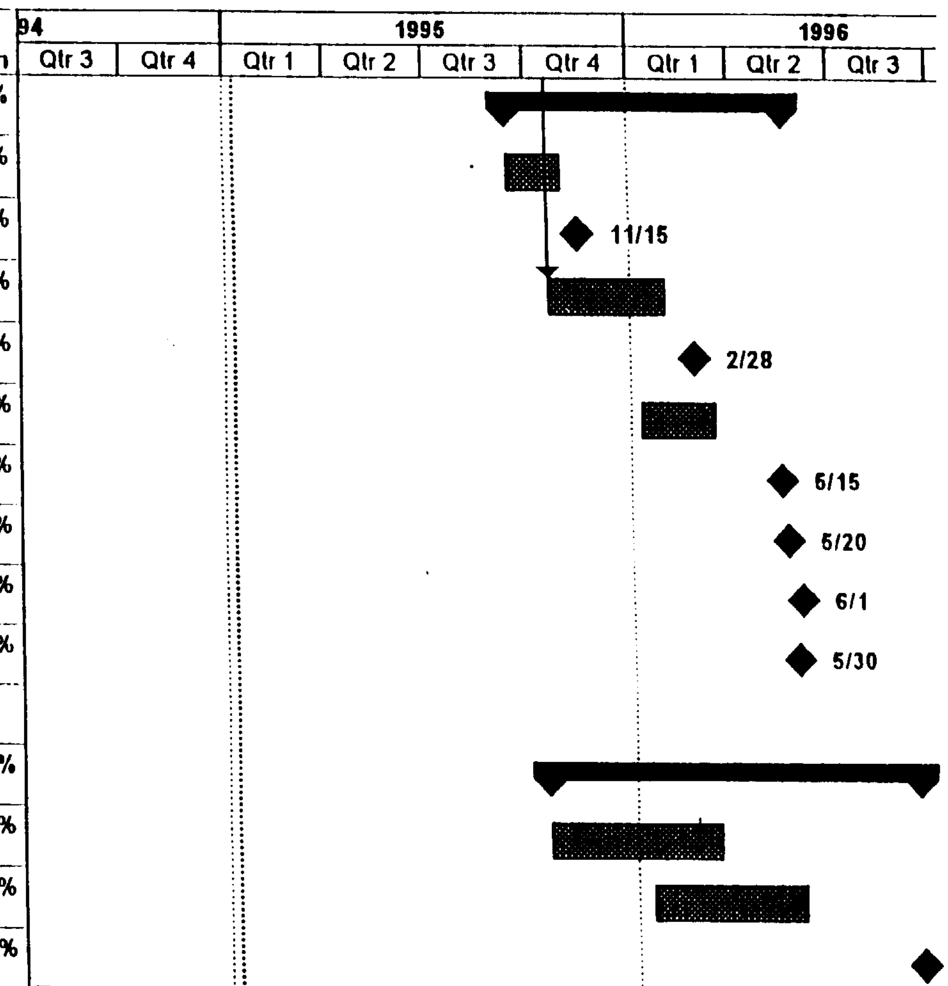
Task Name	Start	Finish	% Com
Data Archive and Retrieval	**8/8/94**	**6/1/96**	**28%**
Archive Requirements	**8/8/94**	**2/24/95**	**53%**
Functional Requirements	8/8/94	10/15/94	100%
ICD Reqm'ts form SSC	10/20/94	10/20/94	100%
Archive/Ground Segment	10/20/94	10/20/94	100%
ICD Approval	1/16/95	2/24/95	0%
Final Archive Arch Def	1/5/95	1/25/95	0%
Archive Protoytpes & Testbed	**10/20/94**	**1/15/96**	**33%**
Testbed Demo	12/15/94	12/15/94	100%
Rapid Proto Testbed Dev	12/15/94	2/20/95	50%
Archive Status Meeting	3/15/95	3/15/95	0%
Proto archive (SSC)	10/20/94	5/17/95	50%
Archive Mgmt & Comm	6/1/95	6/1/95	0%
Prototype Archive Update	4/17/95	9/1/95	0%
System Procurement Compl.	1/15/96	1/15/96	0%



Archive Integration and Test Schedule

Archive Integration and Test Covers 9 months Starting in Late Summer 1995

Task Name	Start	Finish	% Com
DMS Integration and Test	**9/15/95**	**5/20/96**	**0%**
Archive Validation Test	9/15/95	11/1/95	0%
Communication Link Chanti	11/15/95	11/15/95	0%
User Handbook Complete	10/20/95	2/1/96	0%
System Integration Complet	2/28/96	2/28/96	0%
DMS/Chantilly Interface	1/10/96	3/15/96	0%
Integrated System Compat.	5/15/96	5/15/96	0%
System Test Complete	5/20/96	5/20/96	0%
Ground System Operational	6/1/96	6/1/96	0%
Prelaunch Data Review Complet.	5/30/96	5/30/96	0%
Data Processing	**10/16/95**	**9/15/96**	**0%**
Proto Level 2 Automated Proces	10/16/95	3/15/96	0%
Processing S/W Operational	1/15/96	5/31/96	0%
First Satellite Data Set to Users	9/15/96	9/15/96	0%



Data Archive System

- Status
  - Functional Requirements Baselined on 10/13/94
  - System Platform and Software Selection Completed on 11/15/94
  - All Software was Procured and Received by 12/1/94
  - Hardware is under Procurement with Delivery Expected in March of 1995.
  - Additional Functionality has been added to the TRW Archive Testbed
    - » Map Query Interface
    - » User Tracking
    - » Data Cube Download Time and Size Estimate
    - » Data Cube Compression Options
  - Mosaic startup kits are available for Sun, PC and Macintosh platforms

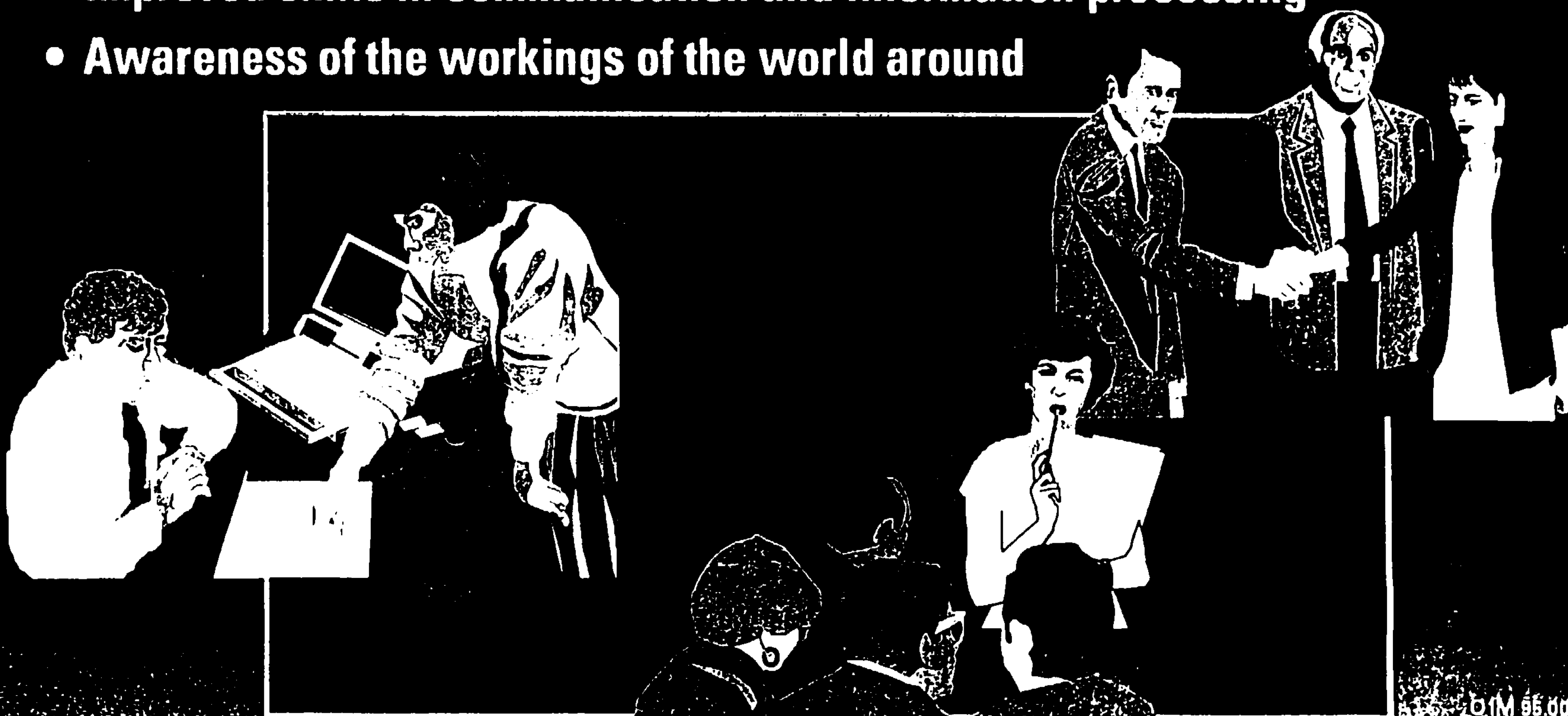
SCIENCE & COMMERCIAL APPLICATIONS
Education

M. Woods

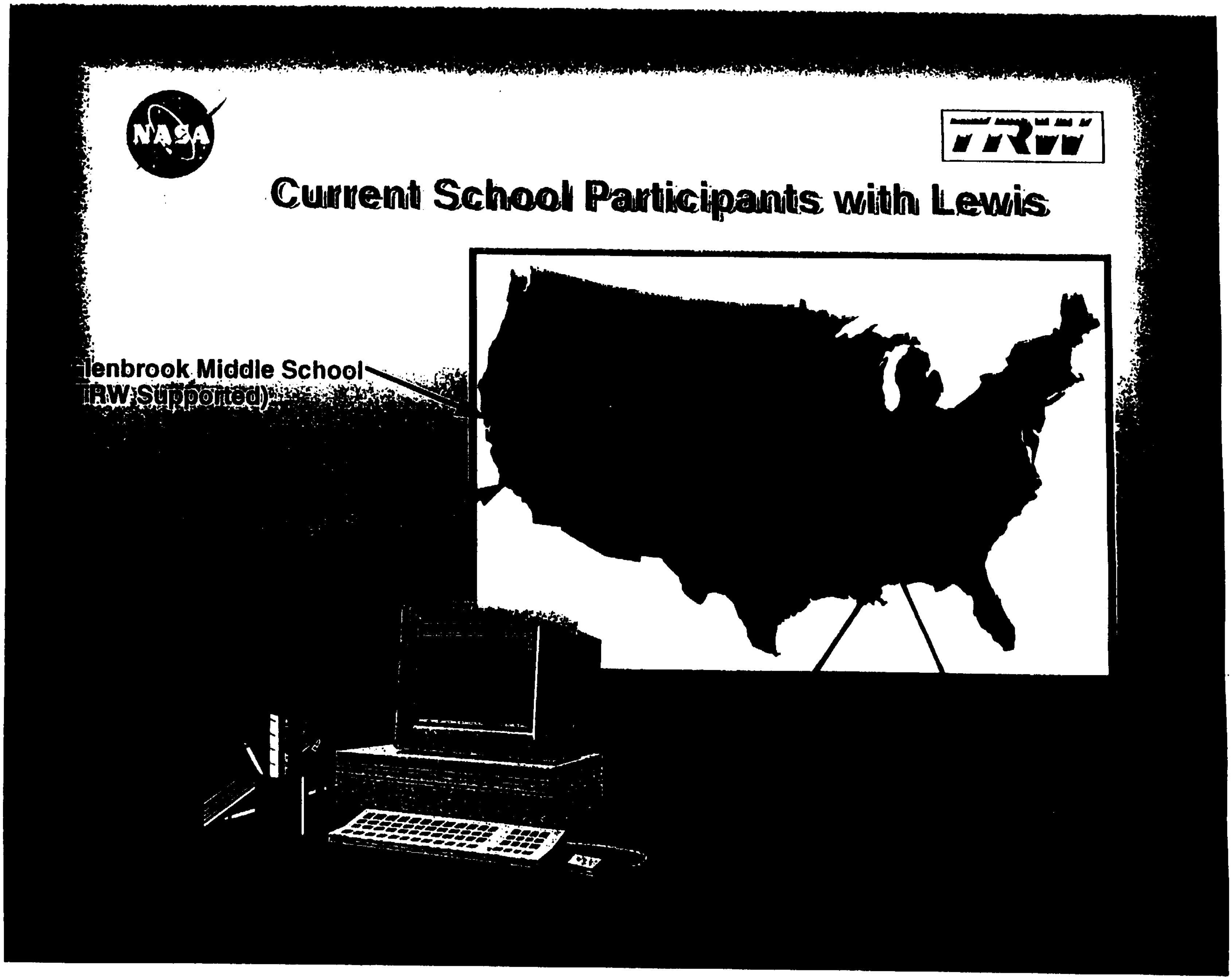
SSTI

Program Reinforces the Development of Hands On Learning and Team Participation

- Relevance to emerging job markets
- Community involvement — give and take
- Management and communication training – technology within multidisciplinary education and integrated product teams
- Improved skills in communication and information processing
- Awareness of the workings of the world around



01M 95.008.007


NASA
TRW
Current School Participants with Lewis
lenbrook Middle School
(TRW Supported)

SSTI

Hands-On Training Sparks Interest and Enthusiasm

Inglewood students get close-up look at the NASA Lear 23

Pilot Bill Colliver briefs Inglewood students

O1M 95.008.001

SCIENCE & COMMERCIAL APPLICATIONS
Applications Development

J. Pearlman

Targeted Applications

Applications were selected to cover a wide range of technological maturity

Relatively Mature: Classification of Agriculture, Forestry, and Minerals, Mapping

Early Development: Environmental change, habitats, plant health and yield

A Gleam in the Eye: Atmospheric pollution, TBD

Applications Test Projects

organization	application area	state
SCIENCE		
Hampton Univ	envir pollution (M508)	Va
Kennedy Sp Ctr	land use mgt (M517)	Fl
Jackson State	mining	Nv
Morgan State	bay environment (M507)	Md
Purdue Univ	agricultural use	In
San Diego State	fire fuel (M512)	Ca
UC Santa Barbara	snow hydrology	Ca
Univ of S. Carolina	environment (M509)	SC

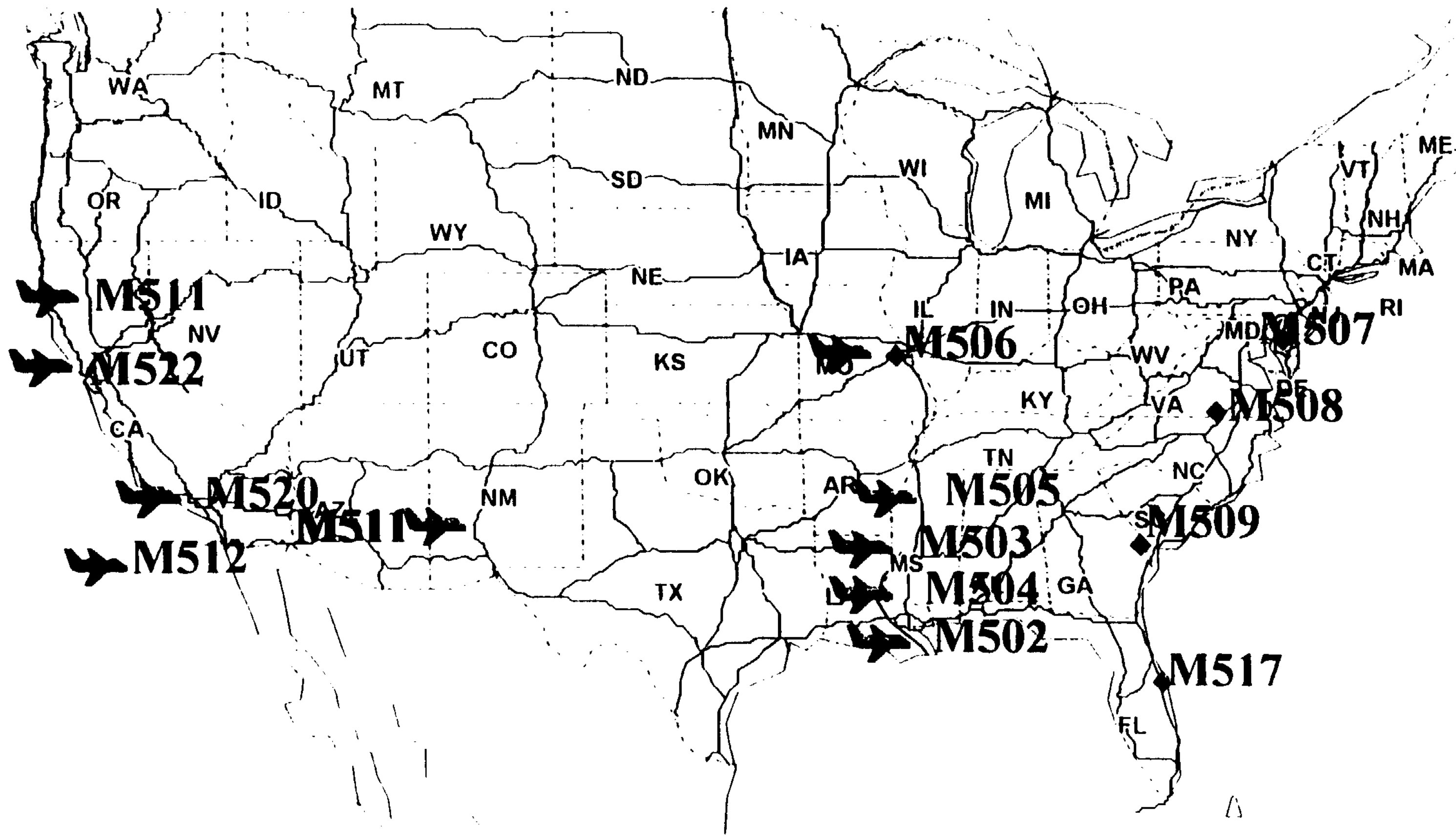
Application Test Projects

organization	application area	state
COMMERCIAL		
Falcon Info Tech	forest and range maps	Ga,Tx
Pacific Meridian	agriculture and wetlands(511)	Ca
TRIFID	environment and urban(506)	Mo,Tx
TRW	forest and military (504)	Ms,
EDUCATION		
Glenbrook M.S.	wetlands (522)	Ca
Inglewood H.S.	urban resources (520)	Ca
W.P. Daniel H.S.	water resources (505)	Ms

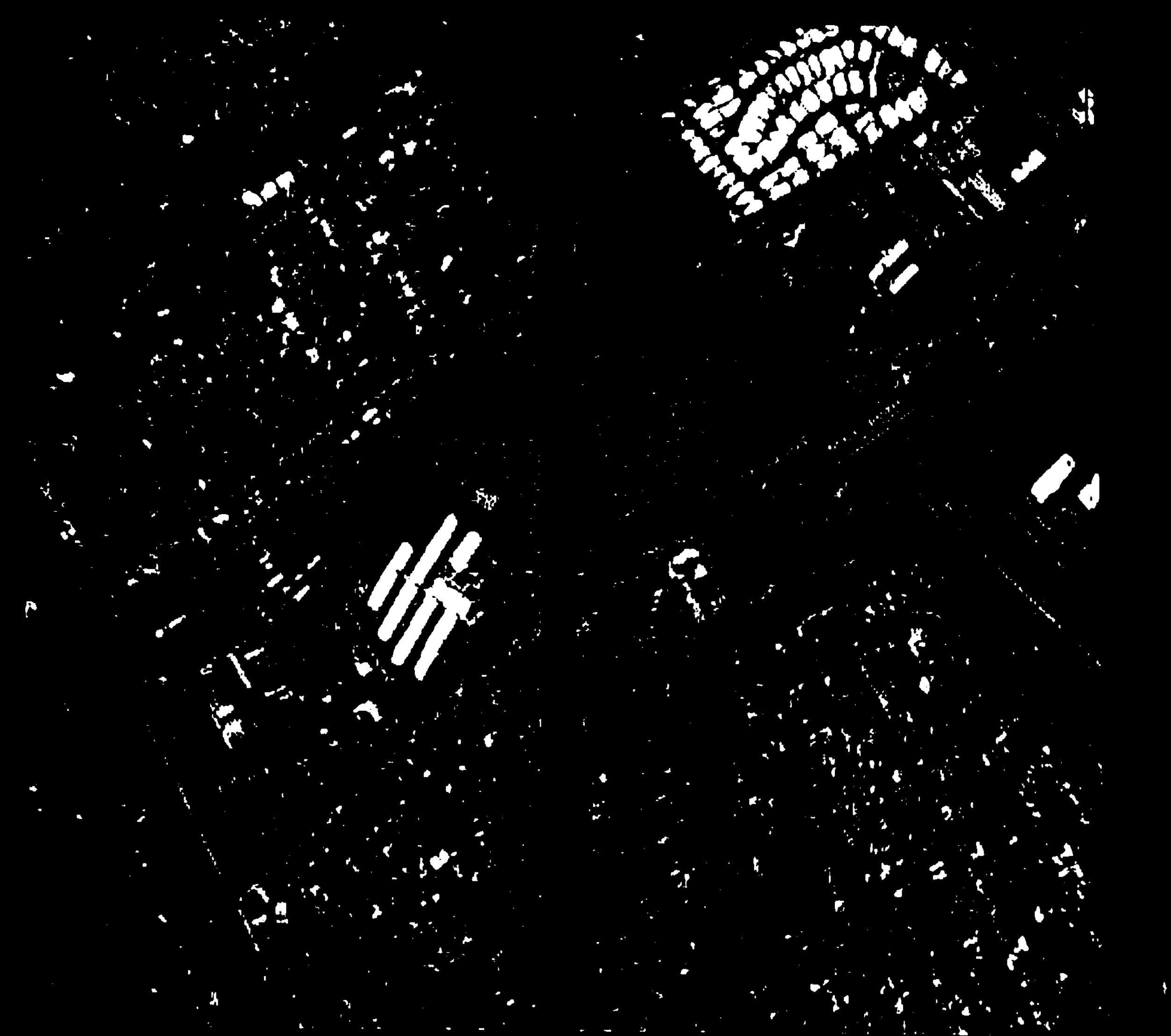
Missions for Fall/Winter '94/'95

Flight Missions Support User Evaluations

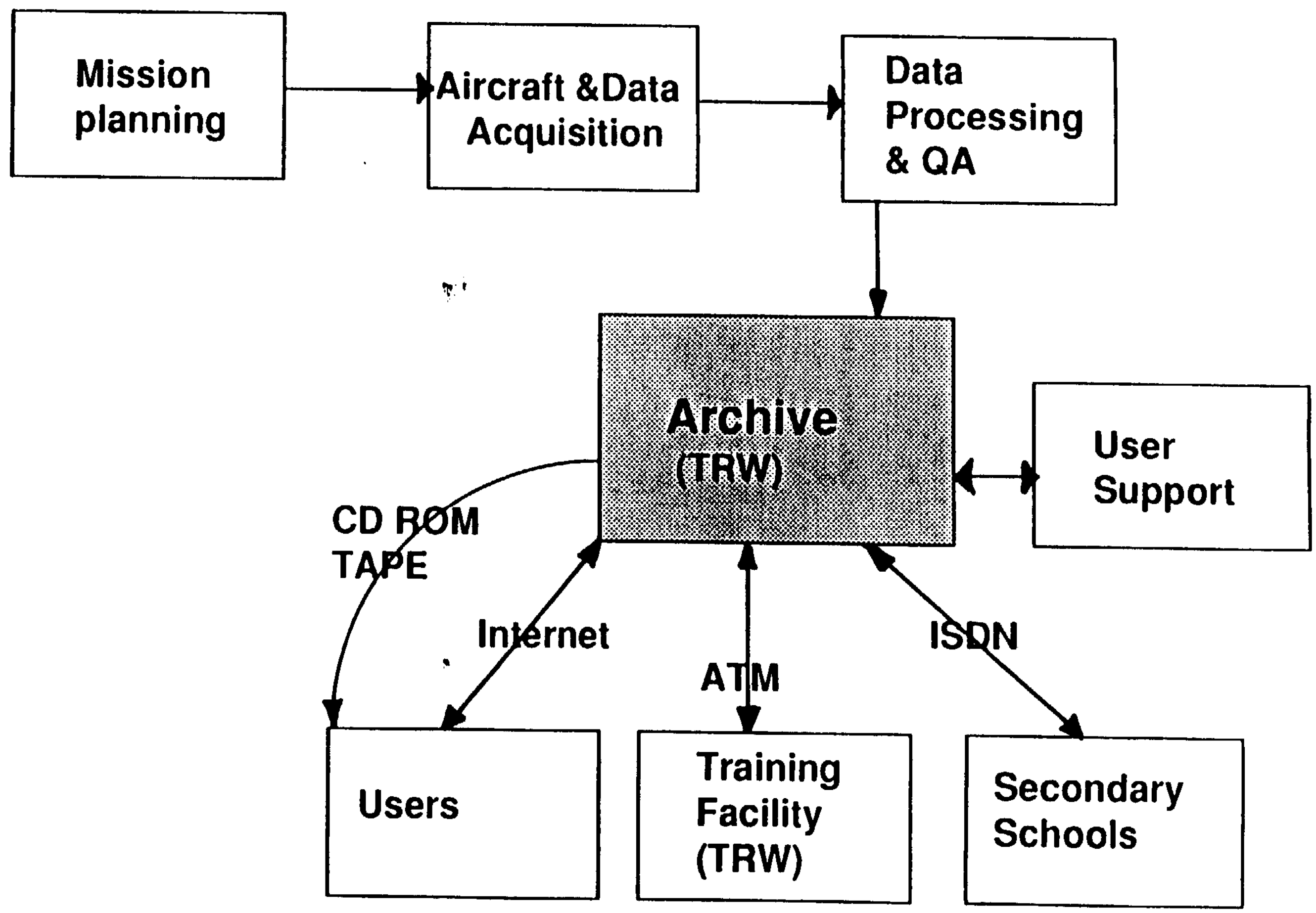
- ◆ TRW MISSIONS PENDING AS OF 12/22/1994
- TRW MISSIONS FLOWN AS OF 12/22/1994
- ◆ TRW MISSIONS PARTIALLY FLOWN AS OF 12/22/199



Small Spacecraft Technology Program (SSTP)
Glenbrook Middle School



Near Term User Data Process



Applications Development Status

Test Site selection and subjects will provide a diverse and balanced demonstration

Commercial partners are putting up their own resources and have started their activities

Science program has been slow to start; indications are that there will be a supplementary funding for HSI evaluation

User Training has started and will continue into summer

User metting planned for spring to look at initial results

SCIENCE & COMMERCIAL APPLICATIONS
Data Policy

M. Watkins

Data Policy and Tasking

Applications IPT review proposed the following policy:

- During first ops year, data will be given to teammates; in second and following years until a commercial source is available, archived data will be provided to all US organizations. Thereafter, a restrictive data distribution policy will be initiated(TBD)
- Tasking priorities will follow NASA HQ guidelines with clarifications, if necessary, referred to the SSTI NASA PM.
- During the first year of operations, TRW teammates will have direct tasking access to the SSTP Lewis Tasking Team(LTT); in following years, tasking requests to the LTT will be through working groups: science/university, education, government and commercial working groups.
- Tasking will be run by the SSTP Lewis Tasking Team consisting of the Level 2 Applications IPT managers, a representative from SOCC, a representative from Nasa Hq and chaired by the Lewis Applications IPT manager.

The above policy is under review by Nasa and at TRW; reviews will occur during January and February.

GROUND SEGMENT
Overview

J. Sarina

SSTI GROUND SEGMENT

- **GROUND SEGMENT CONSISTS OF THE GROUND STATION AND MISSION OPERATIONS**
  - INCLUDES HARDWARE, SOFTWARE, PERSONNEL AND DOCUMENTATION (PROCEDURES)

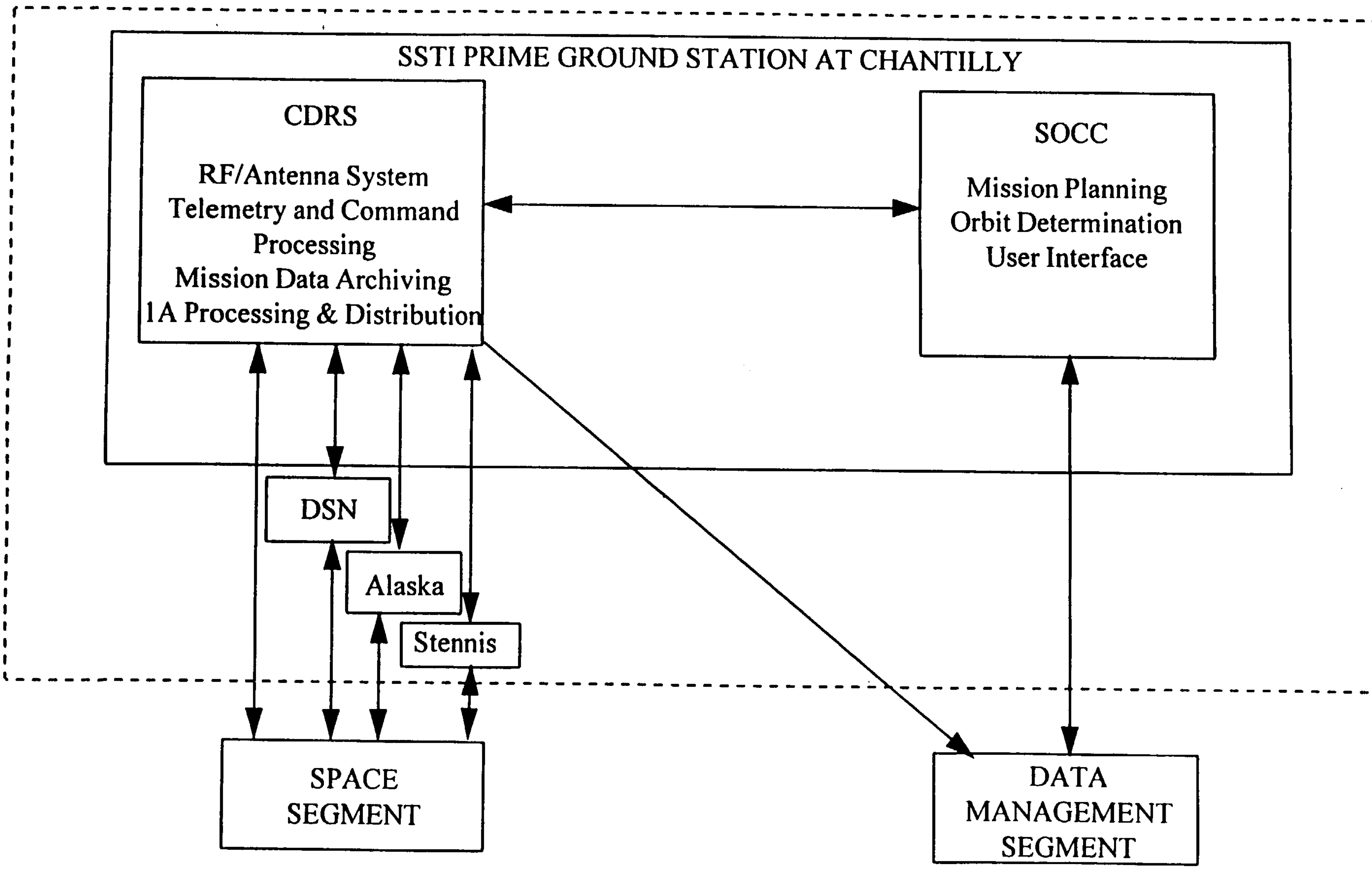
- **REQUIREMENT IS TO SUCESSFULLY EXECUTE THE SSTI LEWIS MISSION FOR THE FIRST YEAR ON-ORBIT**
  - "SUCCESSFULLY" IS DEFINED BY THE TOP LEVEL SPECIFICATIONS AND THE AWARD FEE METRICS
  - ROUGHLY SPEAKING THE CRITERIA ARE; 1) COLLECT ONE GIGABIT OF PAYLOAD DATA PER WORKING DAY, 2) OPERATE ALL THREE PRIME PAYLOADS AND ALL TECHNICAL DEMOS, AND 3) MAINTAIN SPACECRAFT AND PAYLOAD HEALTH THROUGH THE ONE YEAR ON ORBIT PERIOD.

SSTI GROUND SEGMENT

- DESIGN IS LARGELY COTS (Commercial Off-The-Shelf)
  - REDUCES COST
  - REDUCES RISK
  - SHORTENS SCHEDULE
  - SIMPLIFIES VERIFICATION

- THE GROUND SEGMENT IS A TEAM EFFORT (IPDT) AMONG:
  - TRW (SEG) OVERALL MANAGEMENT
  - HARRIS CDRS
  - TRW (SIG) SOCC
  - ALLIED MISSION PLANNING AND OPERATIONS
  - J&T SYSTEM AND SUBSYSTEM EXPERTISE
  - NASA WALLOPS DSN, ALASKA (lead agency)
  - NASA STENNIS RECEIVE ONLY SITE

SSTI GROUND SEGMENT



SSTI GROUND SEGEMENT

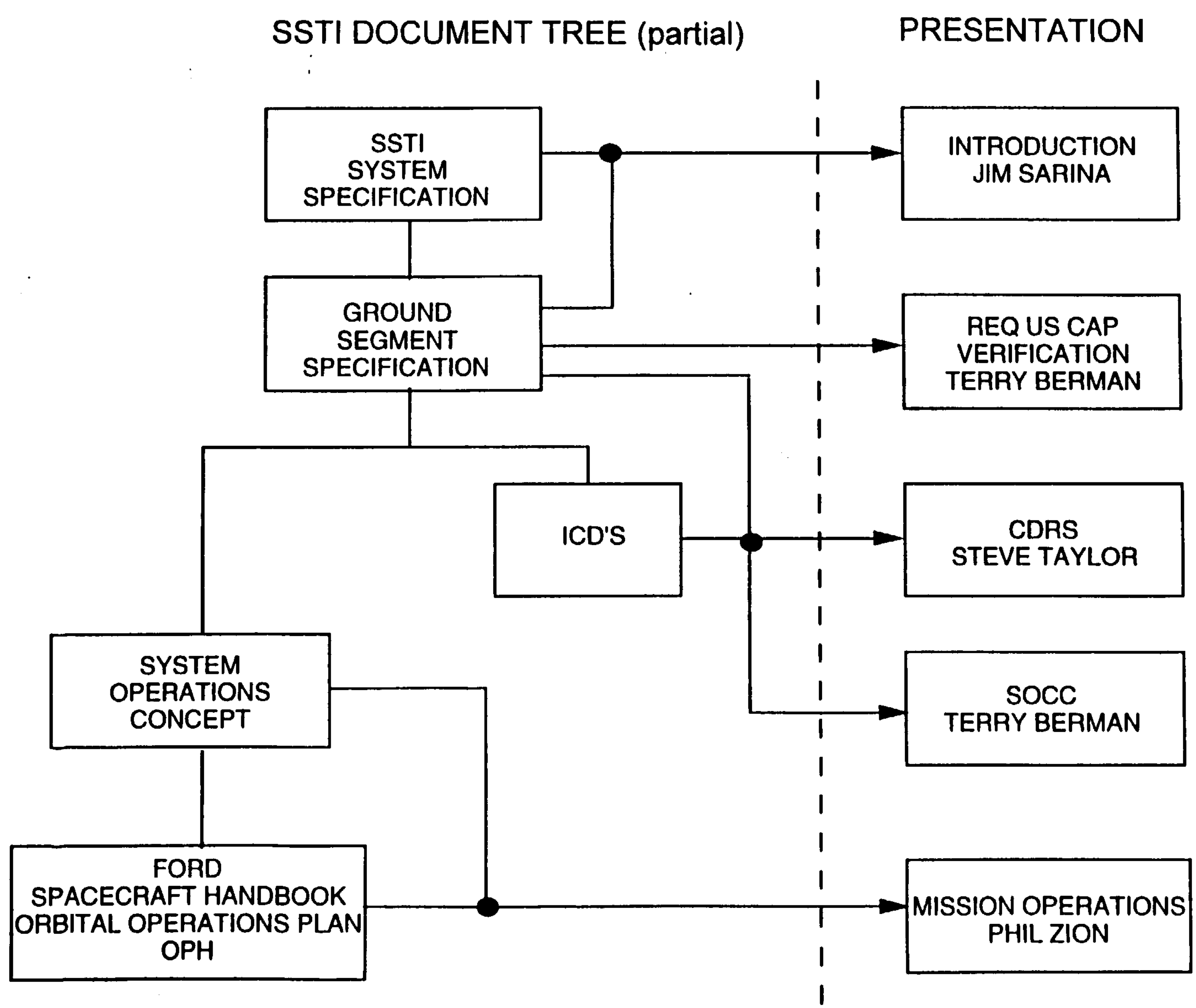
- The prime ground station at Chantilly includes the following
  - CDRS (Command and Data Reception System, Harris Corp): Includes a 12 foot, three axis antenna, all RF uplink/downlink equipment, a Nighthawk realtime computer, GPS time reference, command/telemetry software, and mission data archive and distribution.
  - SOCC (Spacecraft Operations Control Console, TRW SIG): Includes orbit determination software, mission planning tools, and interface to user community/tasking committee.

- DSN (Deep Space Network, NASA): Provides remote command and telemetry sites. Used for initial checkout and available for contingency purposes during normal operations.

- Alaska (NASA): Provides remote command and telemetry site. Used for initial checkout, normal operations, and contingency operations.

- Stennis (NASA): Provides remote telemetry receive-only site during normal operations.

SSTI GROUND SEGMENT



GROUND SEGMENT
Requirements

T. Berman

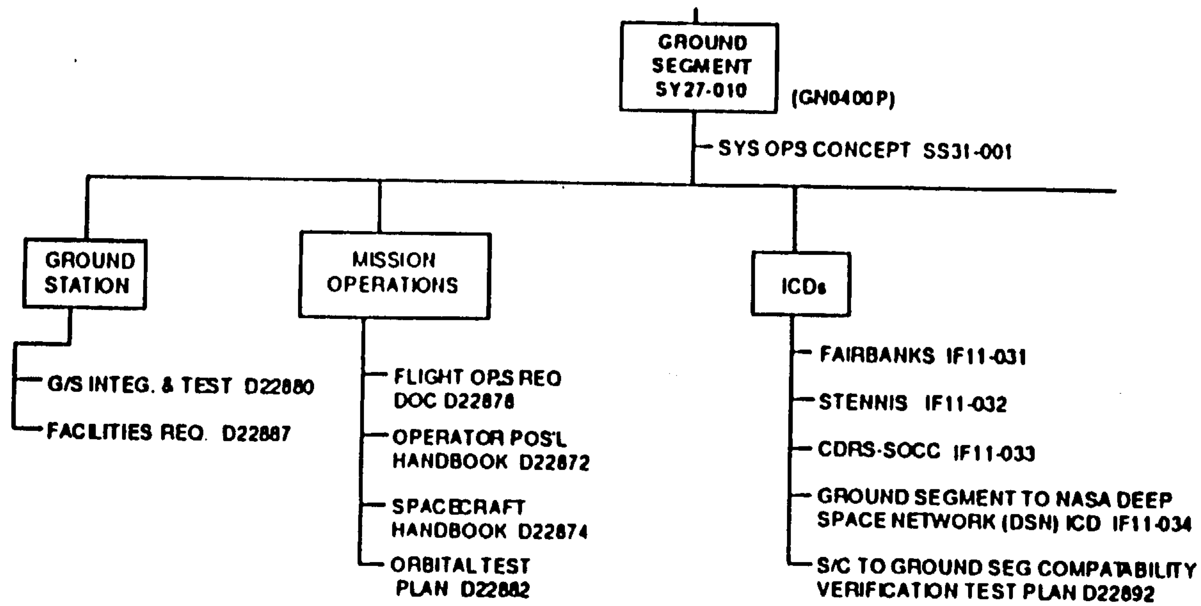
SSTI

Ground Segment Requirements
Agenda

TRW

- Ground Segment Documentation
- Requirements Allocation
- Requirements Verification Approach
- Functional Requirements
- CDRS Requirements
- SOCC Requirements
- RF Survey
- Tool Selections

Ground Segment Documentation

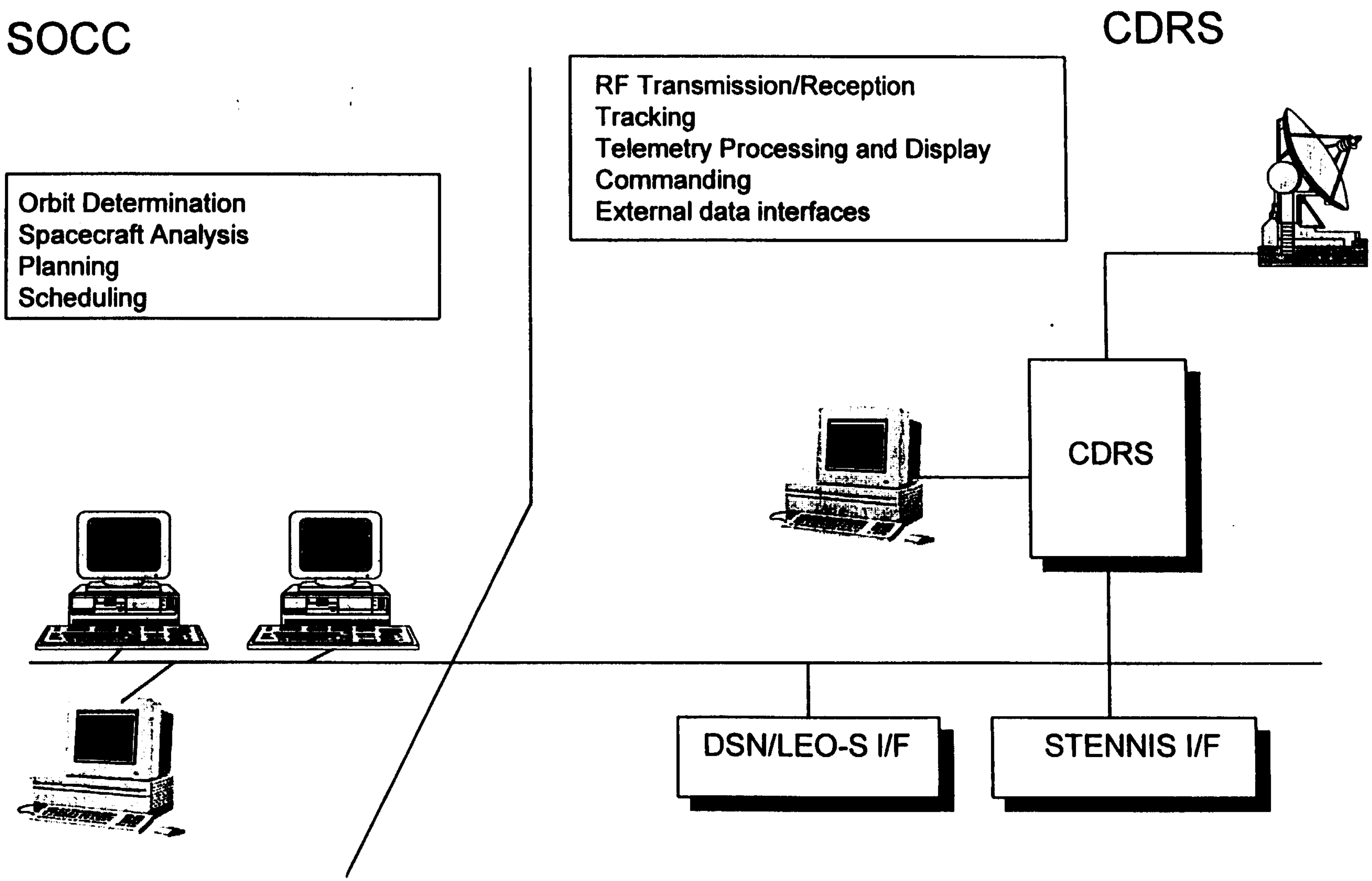


CDRS Documentation

CDRS Prime Item Dev. Spec.

- Acceptance Test Plan
- Acceptance Test Procedures
- Training Documentation
- End Item Development Package
- ICD(s)

Requirements Allocation



Ground Segment Verification Plans

Requirements Area	Primary Verification Method	Documentation
Telemetry Processing	Test/Demonstration	Acceptance Test Plan/Procedures
Commanding	Test/Demonstration	Acceptance Test Plan/Procedures
RF Transmission/Reception	Test/Demonstration	Acceptance Test Plan/Procedures
External Interfaces	Test/Demonstration	Interface Control Document Integration, Test, Verfication Plan
Tracking	Test/Demonstration	Acceptance Test Plan/Procedures
Orbit Determination	Test/Analysis	Integration, Test, Verification Plan
Planning/Scheduling	Test/Analysis	Integration, Test, Verification Plan

SSTI

Functional Requirements (1 of 2)

TRW

Requirement	Capability
•Transmit Commands to the Spacecraft •Receive, Store, and Process Telemetry from the Spacecraft •Maintain Communication through a contact •Create Schedule of Spacecraft Commands •Create and maintain log of commands	CDRS RF Equipment in combination with the COMET and VEDA (OMEGA) software tools.
•Reconsititute data files from stored telemetry •Generate files consisting of non-redundant time ordered data from individual spacecraft subsystems •Generate files consisting of non-redundant sequenced data from individual experiments	CDRS Software
•Transmit spacecraft subsystem and experiment data to Stennis Space Center •Transmit data quality assessment reports to Stennis Space Center •Exchange information with DSN and Alaska	CDRS Software, COMET tool, CDRS interface hardware, SOCC software

SSTI TRW

Functional Requirements (2 of 2)

Requirement	Capability
•Receive requests from Stennis Space Center •Convert tasking requests to spacecraft commands	Communications provided via interface H/W and CDRS S/W. Comet tool provides for conversion of tasking requests.
•Determine spacecraft orbit •Predict spacecraft orbit	OASYS tool executing on SOCC
•Predict and schedule spacecraft contact times	OASYS tool provides for prediction. PC-based tools used to create schedule (e.g., Excel)
• Implement measures against physical or electronic breaches of security	Building Security, Cipher lock access to ground station facility, password protection on workstations, physical disconnect from building LAN

CDRS Requirements (1 of 4)

Requirement	Capability
Tracking	
•Track S/C continuously through all contacts when S/C is above 5 deg elevation Perform Closed-loop tracking Perform Program tracking (System Specification requires 3 db margin)	12 ft. dish can be driven horizon to horizon. 11.3 db/K G/T provides 6 db margin at 5 deg. elev. ACU/receiver/antenna support both closed loop and program track
•Provide frequency reference capability •Provide time reference capability	Frequency provided by counter (3 E-09 accuracy) Time provided by GPS receiver
•Provide an audible alarm at the antenna when tracking	Relay activates alarm when antenna is in motion
•Provide doppler vs. time data during all contacts •Provide ant angle/elev vs. time	ACU/receiver/ATPS provide data
•Detect and report AOS and LOS •Detect and report anomalous data dropouts •Re-establish synchronization	Receiver indicates lock following signal acquisition loss of lock at LOS CDRS S/W will re-synch and also provide dropout notification
•Provide metrics: % data units valid No. of data units received	CDRS software will maintain statistics of received frames

SSTI

CDRS Requirements (2 of 4)

TRW

Requirement	Capability
Commanding	
•Transmit uplink bitstreams to the spacecraft •Provide for 2.00 Kbps GSTDN commanding •Terminate transmission upon operator action	CDRS modulator, HPA, in combination with COMET
•Generate individual commands for execution at scheduled time •Format validated commands and command sequences •Validate conformance of any commands •Validate conformance of any bitstream	COMET CCL provides operator command interface. COMET data base used to perform command validation.
•Display command and configuration data VCC,GCC Time of last command Time of next command	COMET will provide GCC, Time of last command, Time of next command. VEDA (Omega) will provide VCC from received telemetry
•Maintain command activity log	COMET provides logging capability

CDRS Requirments (3 of 4)

Requirement	Capability
Telemetry	
•G/T of 11.3 db/K at 5 deg elev.	G/T 11.3 db/K at 5 deg.
•Receive mode 1 (8 Kbps) or mode 2 (2.048 Mbps) TLM •Viterbi decode received TLM •Store all received TLM	Microdyne receiver, viterbi decoder in Nighthawk, COMET used to store TLM
•Display in real time 2000 measurands (i.e., SOH)	Capability estimated at 10K measurands
•Accept definition of TLM stream format •Allow modification of TLM format •Provide for subcommutation and super commutation •Provide for measurand conversion (e.g., table look up, formula, bit manipulation, etc.)	Supported by VEDA (Omega) and COMET
•Display measurands •identify as green, yellow, red •playback •measurand(s) vs. time	Supported by VEDA (Omega) and COMET

CDRS Requirements (4 of 4)

Requirement	Capability
Data Distribution	
•Transmit command data to specified command stations (i.e., DSN, Alaska) •Receive telemetry data from specified telemetry stations (i.e., DSN, Alaska)	Provided by COMET via agreed interface with DSN and Alaska
•Transmit data files to Stennis Space Center	Provided through UNIX utilities via agreed interface with Stennis

SOCC Requirements (1 of 2)

Requirement	Capability
Planning	

•Generate ephemeris based on received tracking data
•Store and retrieve history of orbital element sets
•Select orbital element sets for estimated error calculation
•Calculate estimated error between selected element sets
•Propagate orbit over any specified time interval
•Calculate and display attitude parameter to support instrument observation
•Generate and display as a function of S/C attitude and time
    •S/C illumination/eclipse periods
    •Ground station contact times
    •Solar and lunar incursions into onboard instruments
    •entry/exit times over South Atlantic Anomaly
    •entry/exit times
 	
•Display graphically or alphanumerically the S/C groundtrack, instrument fields of view/regard
 	
•Display as a function of S/C attitude and time instantaneous FOV and FOR during orbit maneuvers, orbit adjusts, and station keeping
	Provided by OASYS

SOCC Requirements (2 of 2)

Requirement	Capability
Scheduling	
•Manage and display schedules for •Tasking requests •Commands •Command Sequences •Orbital Opeartions and events •Ground operations and events	Provided by PC-based tools (e.g., Excel) COMET
•Generate contact plans based on schedules	
Analysis	
•Manage on-orbit utilization of power, momentum, maneuvering, memory propellant, thermal resources	Provided by PV-WAVE, PC-based tools (e.g., Excel, Matlab, Mathematica, etc.) and LAN interconnect to SOCC for subsystem engineering support

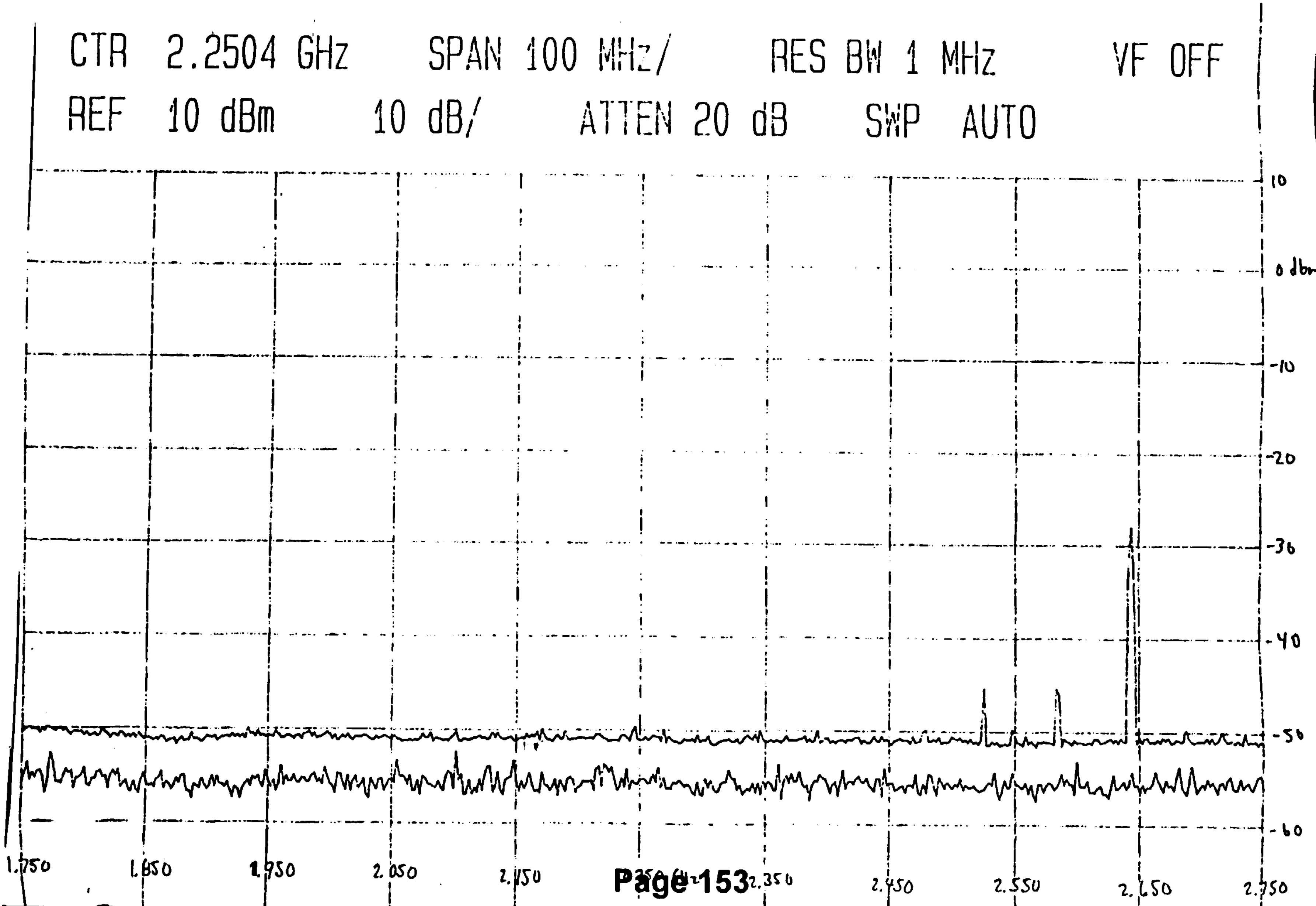
SSTI

RF Survey

TRW

- Objective
  - Determine whether there will be significant interference to the TRW/Chantilly Ground Station
- Approach
  - Measure RF emitters in all directions from the TRW/Chantilly G/S Location
    - Perform 360 degree sweeps
    - Long term (24 hour) North towards Dulles International Airport, South towards Commercial Microwave Tower, and Southeast towards TDRS-4
- Results
  - No Sources of Interference were detected
  - Commercial/Government S-band sources were found but all were operating at frequencies far removed from the LEWIS frequencies

RF Spectrum Plot from RFI Test



SSTI

Ground Station License

TRW

- National Telecommunications and Information Administration (NTIA) has regulatory authority for government use of spectrum
- Request for authority to transmit from TRW/Chantilly was submitted to NASA
- NASA performed frequency interference study and recommended a “Stage 3” review for the LEWIS system. (Oct 1994)
  - Uplink Freq. 2095.172 MHZ
  - Downlink Freq. 2275.300 MHZ
- Air Force Member of Spectrum Planning Subcommittee required further interference study
- Air Force approved use of frequencies by Lewis (Jan 1995)
- “Stage 4” review (final) to be submitted for approval to operate

SSTI

Orbit Determination and Planning Tool

TRW

Evaluation Area	OASYS	STK/PODS
Orbit Determination	X	X
Orbit Propogation	X	X
Maneuver Planning	X	
Graphical User I/F	X	X
Input Data Types	X	X
Event Planning	X	X
Cost	$35K	$20K

Evaluation performed via demonstrations, vendor site visits and examination of product manuals.

AFSCN has identified OASYS as next generation tool

OASYS selected for use in SOCC, primary discriminator was maneuver planning, secondary discriminator was orbit determination (PODS is new product - no track record)

Command/Telemetry Tool Trade Study

Criteria	Wt.	Comet		OASIS-CC	
		Score	Total	Score	Total
Implementation Cost	3	3	9	1	3
Ease of use	2	1	2	2	4
DB Population	2	2	4	2	4
Extensibility	1	2	2	2	2
Customer Support	1	2	2	1	1
Documentation	1	2	2	3	3
Installed Base	1	1	1	2	2
Standards	3	3	9	3	9
Totals			31		28

COMET selected for SSTI; already hosted on Nighthawk leading to lower risk/cost

COMET was selected by Motorola for use on IRIDIUM

SSTI

TRW

GROUND SEGMENT
CDRS Design

S. Taylor (Harris)

OUTLINE

1. CDRS Requirements
2. System Design
3. Hardware Configuration Item Design
4. Computer Software Configuration Design
5. Program Execution and Scheduling
6. Test and Verification

CDRS Requirements

- **Functional Requirements from TRW SOW & Ground Station Requirements Document**

- **CDRS Space/Ground Segment Performance Requirements:**

Tracking:	300 - 550 km Altitude satellite
Transmit Band:	2020 - 2120 MHz
Receive Band:	2200 - 2300 MHz
EIRP:	42 dBw
G/T:	11.3 dB/°K
BER:	1×10^{-9} (with Veterbi decoding)
Uplink:	2.0 kb/s, NRZ-M, BPSK, 16 kHz subcarrier (STDN)
Downlink:	8 kb/s, coded, NRZ-M
	2048 kb/s, coded, NRZ-M

CDRS Requirements - (Continued)

- **CDRS Ground/Ground Performance Requirements**

  Transmits Spacecraft Commands

  Receives Time Ordered, Separated by Bin, non-redundant Data Products

  Provides a Data Quality Metric

  Capability to Send Data to Stennis Space Center

  Capability to Receive Unprocessed data from Stennis Space Center, Univ. of Alaska

  Capability to Communicate with the DSN for LEO Contingency Operations

  Provides Spacecraft Status of Health (SOH) Processing and Display

  Provide CDRS Elevation, Azimuth, and Doppler Rate data to SOCC

- **Environmental (Outdoor Equipment)**

Temperature	
Wind	≤ 45 mph operating ≤ 110 mph with gusts
Weight	< 2000 lbs

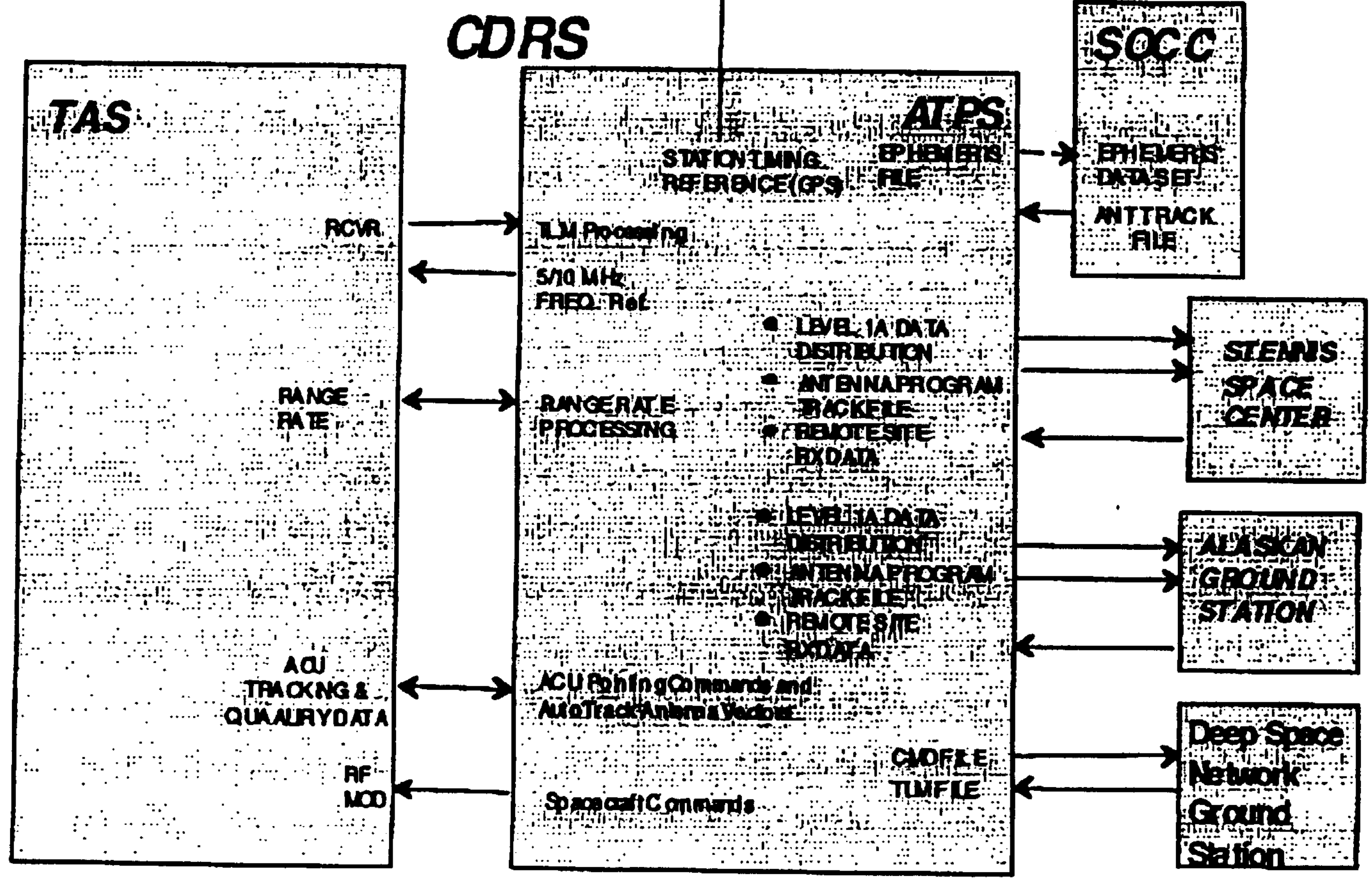
CDRS System Design

- **Three Subsystems:**
  - Transmit Antenna Subsystem (TAS)
  - Data Processing Subsystem
  - WAN Distribution Subsystem

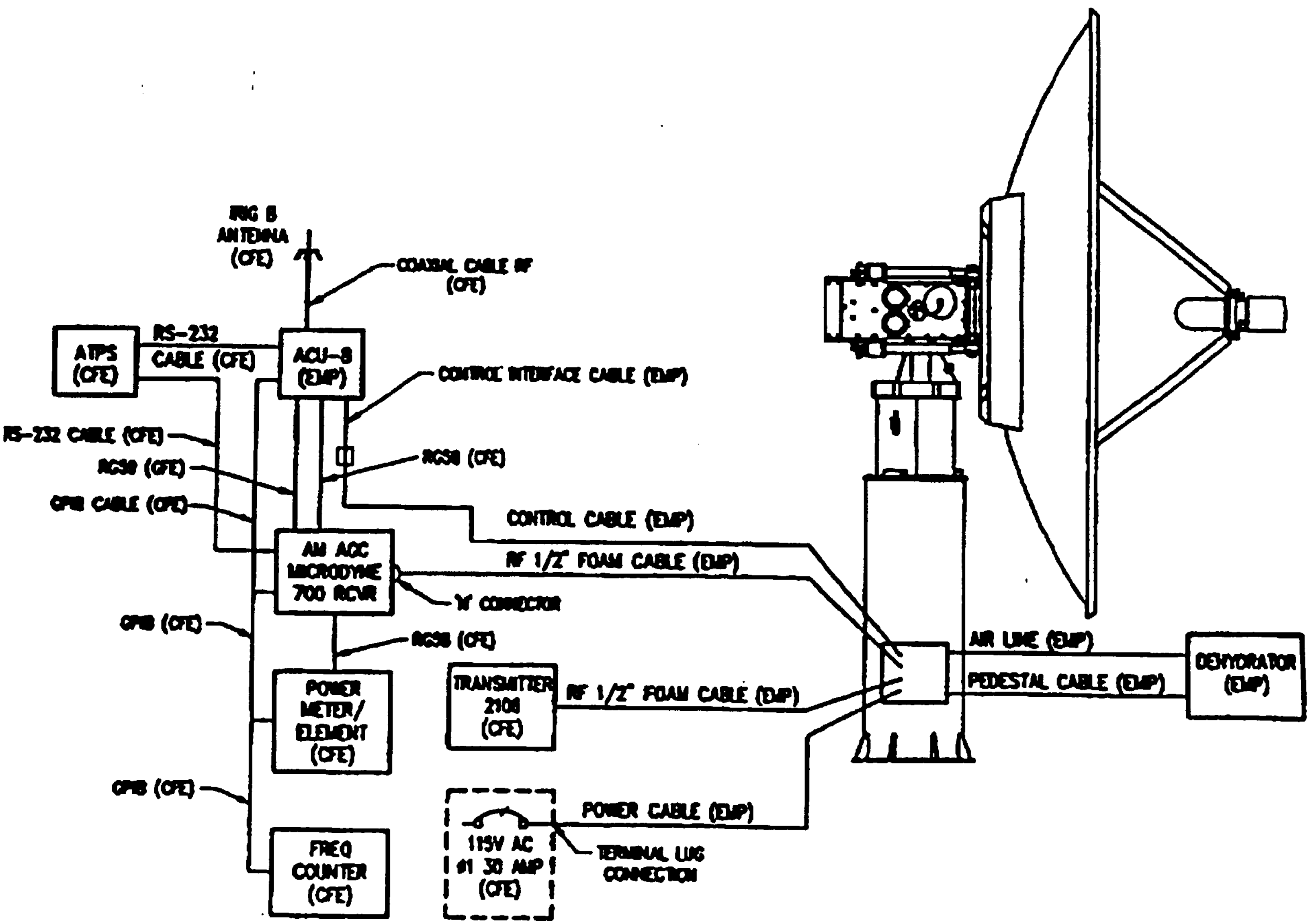
- **Risk Management Activities**
  - Component Selection - Select COTS components when possible
  - Minimize Hardware Development
  - Minimize Software Development
  - Use COTS software tools where possible

Hardware Configuration Item Design

Spacecraft/Ground Link

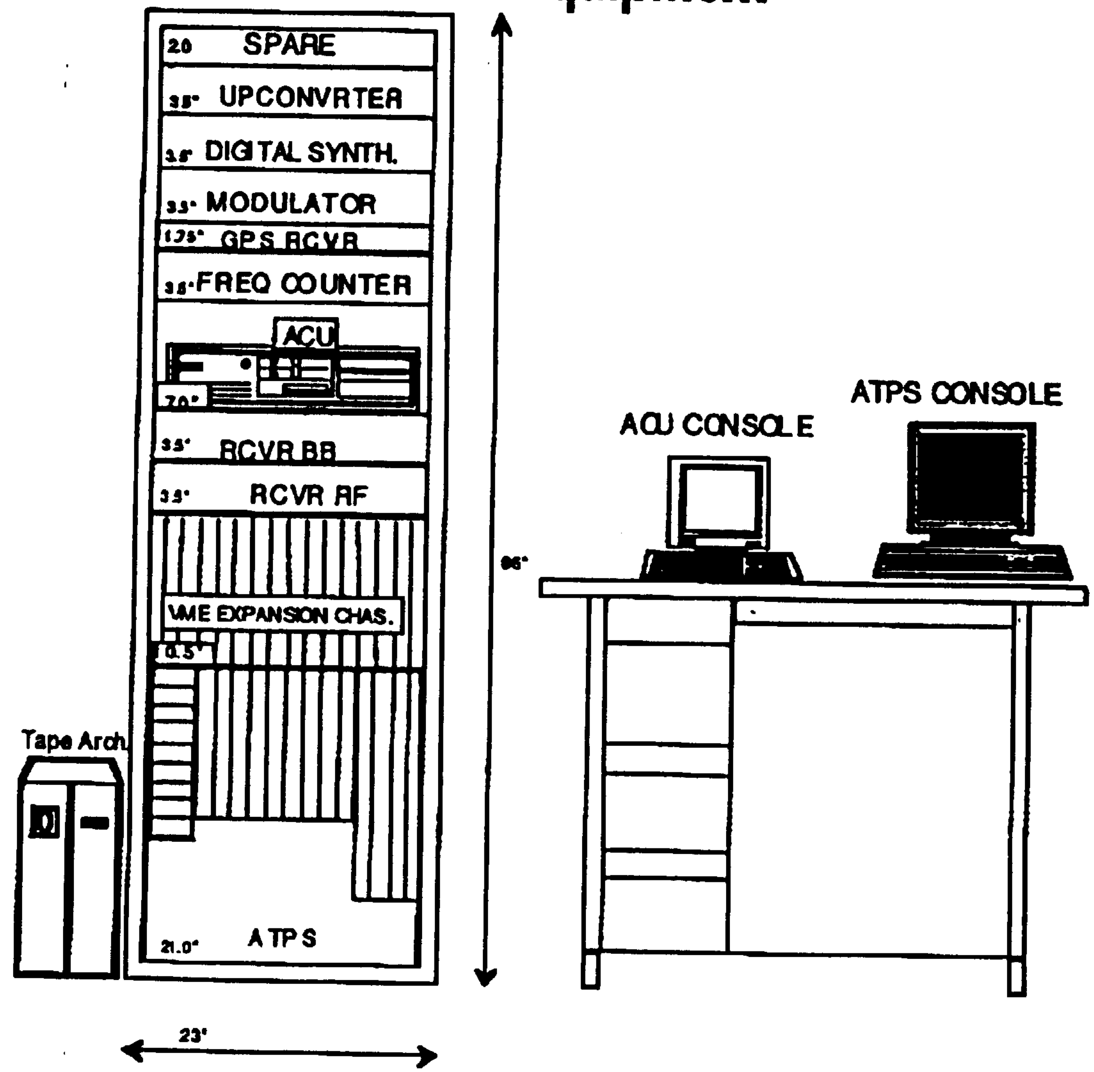


CDA

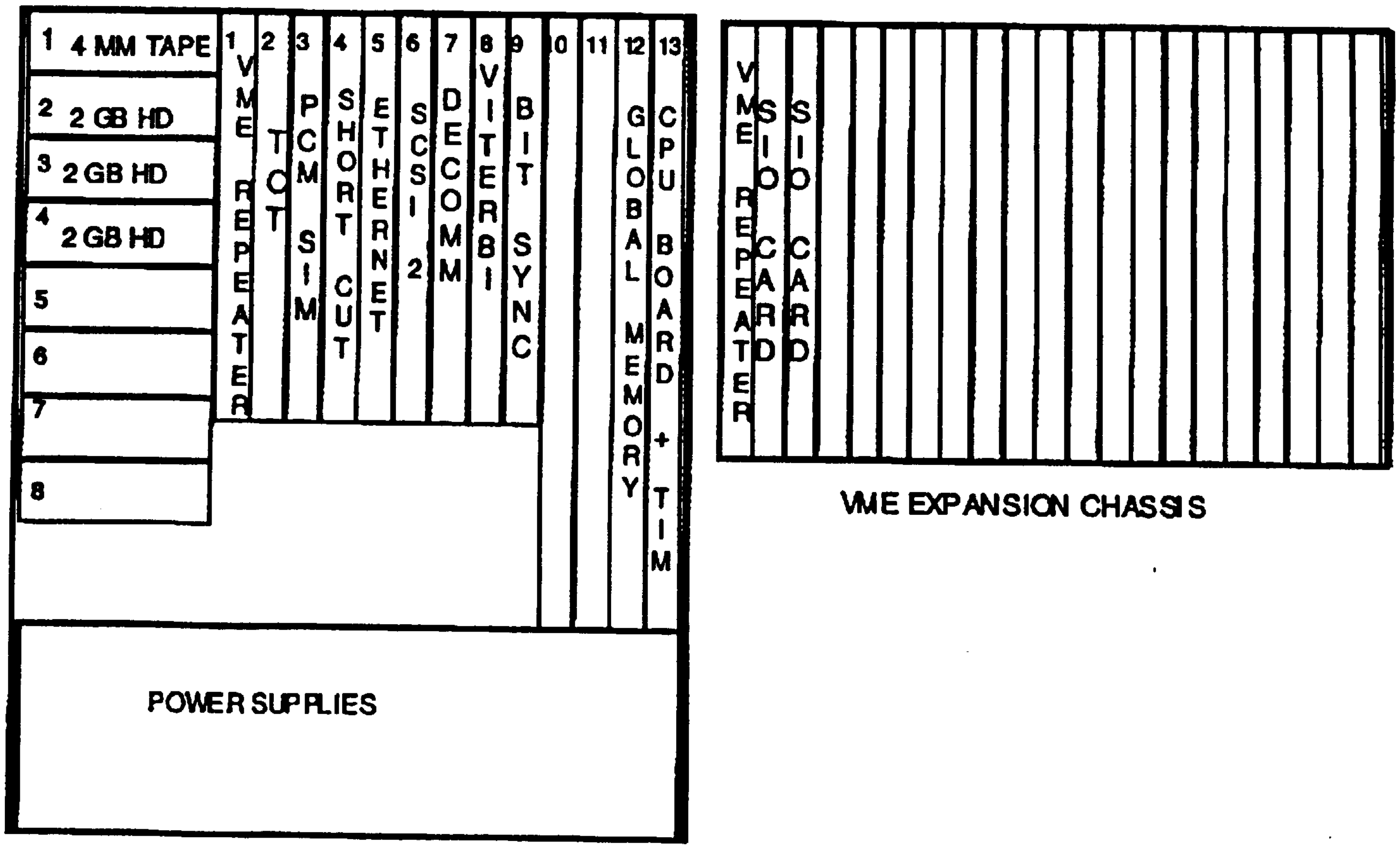


IRIG B ANTENNA (CFE)
COAXIAL CABLE RF (CFE)
ATPS (CFE)
RS-232 CABLE (CFE)
ACU-8 (EMP)
CONTROL INTERFACE CABLE (EMP)
RS-232 CABLE (CFE)
RG58 (CFE)
RG58 (CFE)
GPIB CABLE (CFE)
CONTROL CABLE (EMP)
AM AGC MICRODYNE 700 RCVR
RF 1/2" FOAM CABLE (EMP)
"N" CONNECTOR
GPIB (CFE)
RG58 (CFE)
POWER METER/ ELEMENT (CFE)
TRANSMITTER 2108 (CFE)
RF 1/2" FOAM CABLE (EMP)
AIR LINE (EMP)
PEDESTAL CABLE (EMP)
DEHYDRATOR (EMP)
GPIB (CFE)
POWER CABLE (EMP)
115V AC ø1 30 AMP (CFE)
TERMINAL LUG CONNECTION
FREQ COUNTER (CFE)

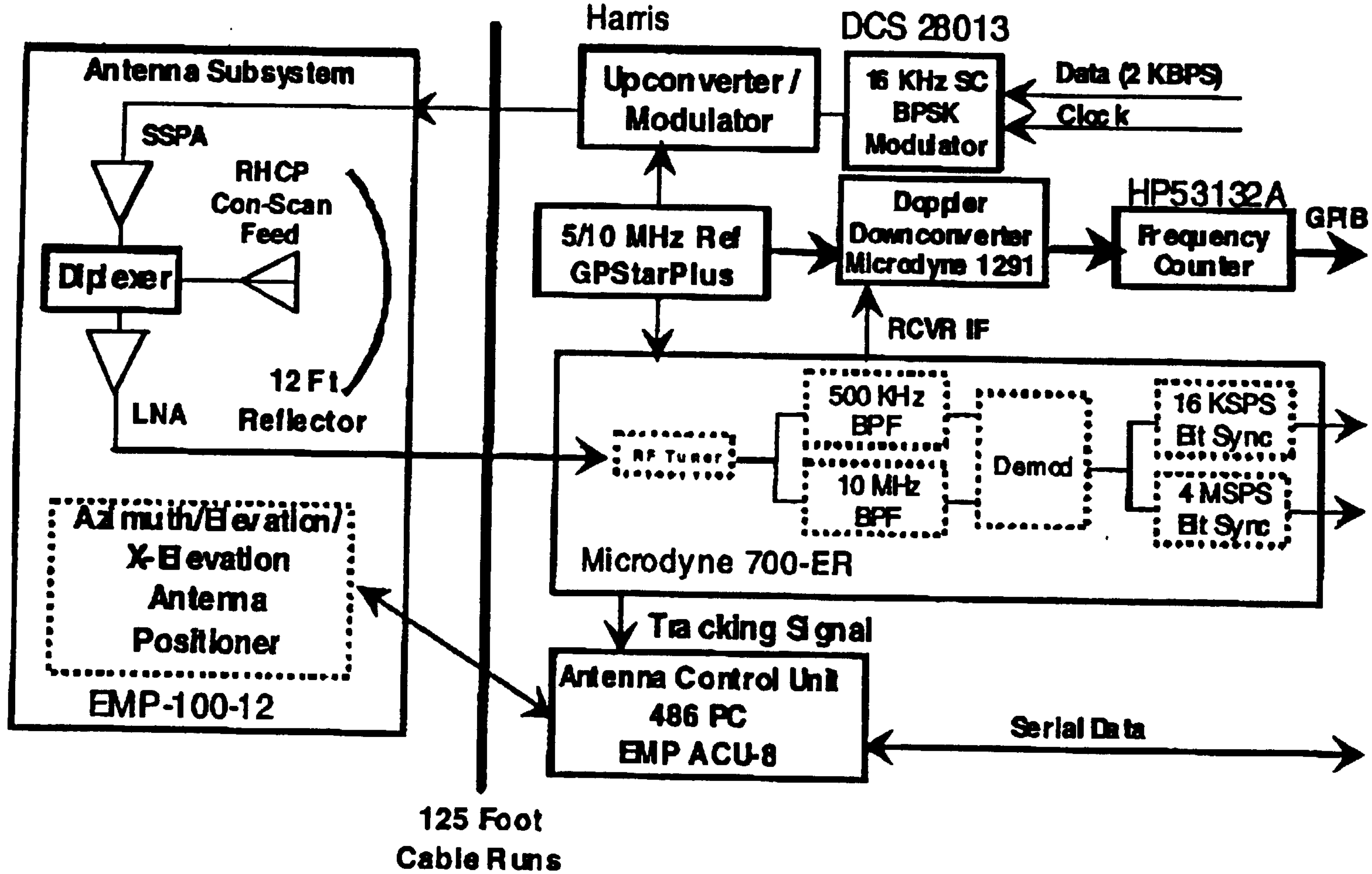
CDRS Equipment



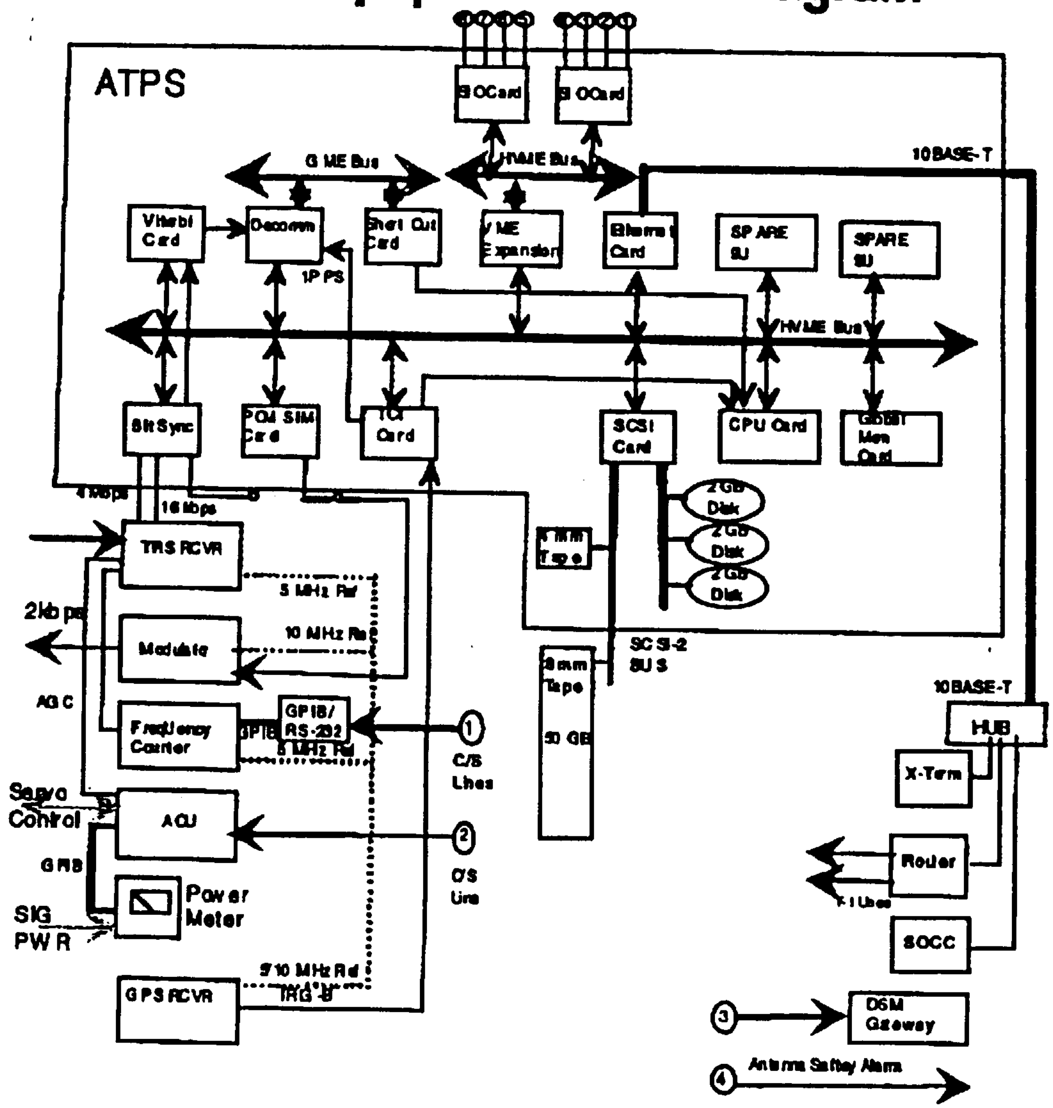
ATPS CHASSIS



CDRS RF Subsystem



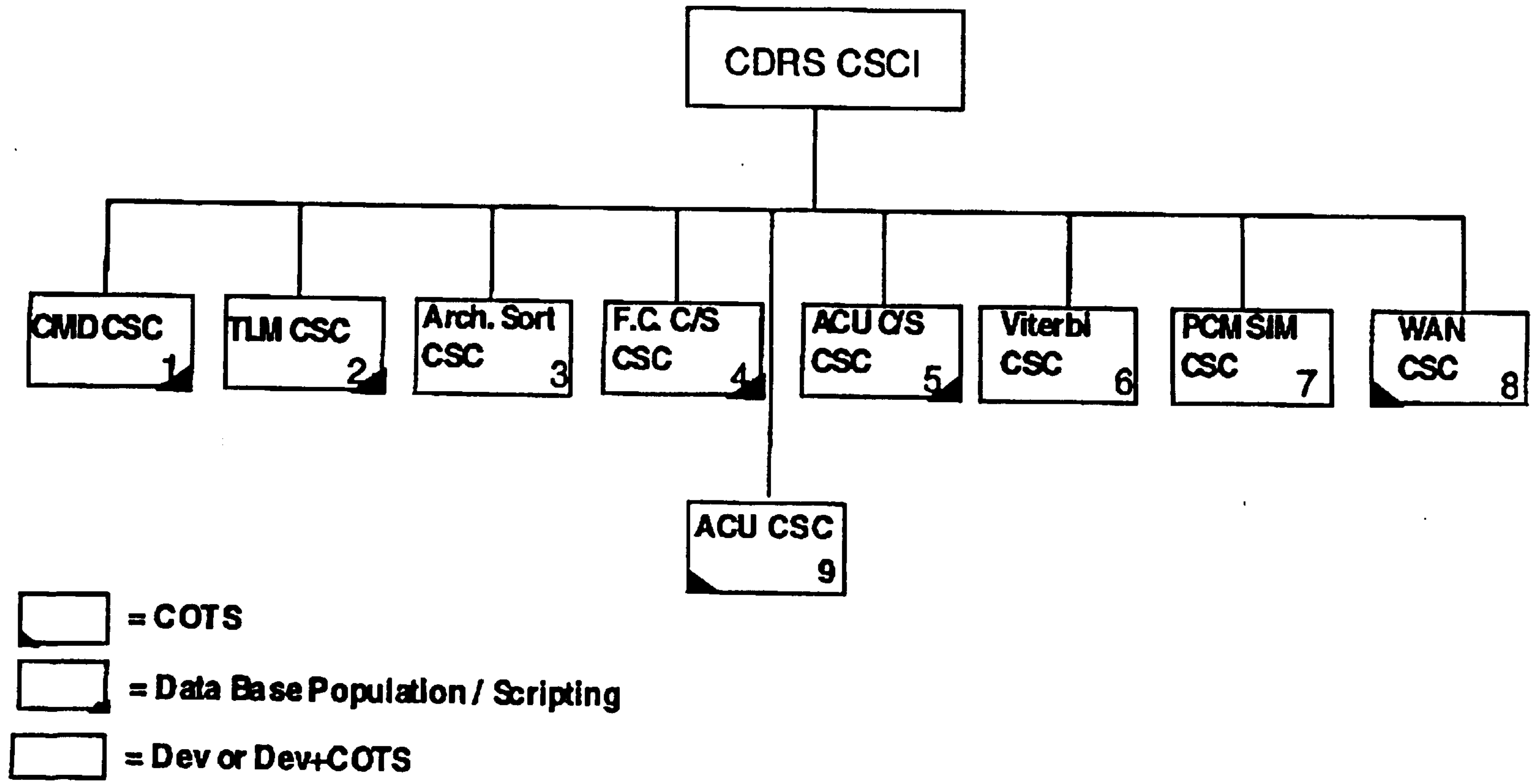
CDRS Equipment Block Diagram



CDRS Deliverable Hardware Items

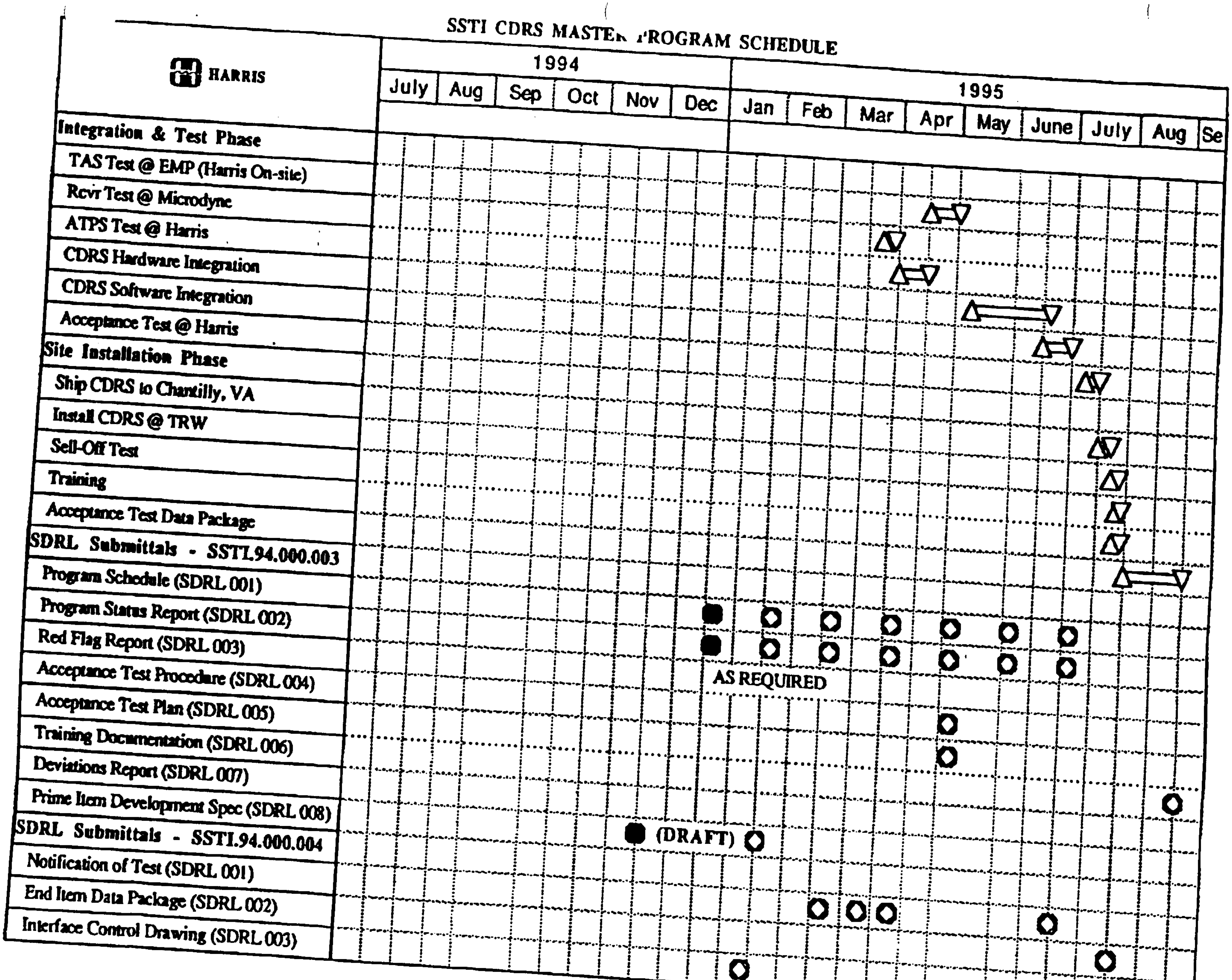
Part No.	ITEM
EMP-100-12	EMP Antenna Pedestal (12 ft)
ACU-8	EMP Antenna Controller (486 PC)
700-MR	Microdyne Receiver/Down Converter
1291-DC	Microdyne Doppler Down Converter
HP53132A	HP Frequency Counter
365-1-2-1-1-1-1-0	Odetics GPS Receiver/Frequency Standard
EXB-10i	Exabyte 8mm Cartridge Handling System
2201	Wellfleet Access Node Router
FA-16376	CableExpress 10Base-T 8 Port Hub
	Harris Linear Phase Modulator/Upconverter
ATPS	Harris Advanced Telemetry Processing System (Night Hawk 5802)
VG8246	Tektronix X-Terminal
	66" Rack
	Manuals

CDRS CSC's


CDRS CSCI
CMD CSC 1
TLM CSC 2
Arch. Sort CSC 3
F.C. C/S CSC 4
ACU C/S CSC 5
Viterbi CSC 6
PCM SIM CSC 7
WAN CSC 8
ACU CSC 9
= COTS
= Data Base Population / Scripting
= Dev or Dev+COTS

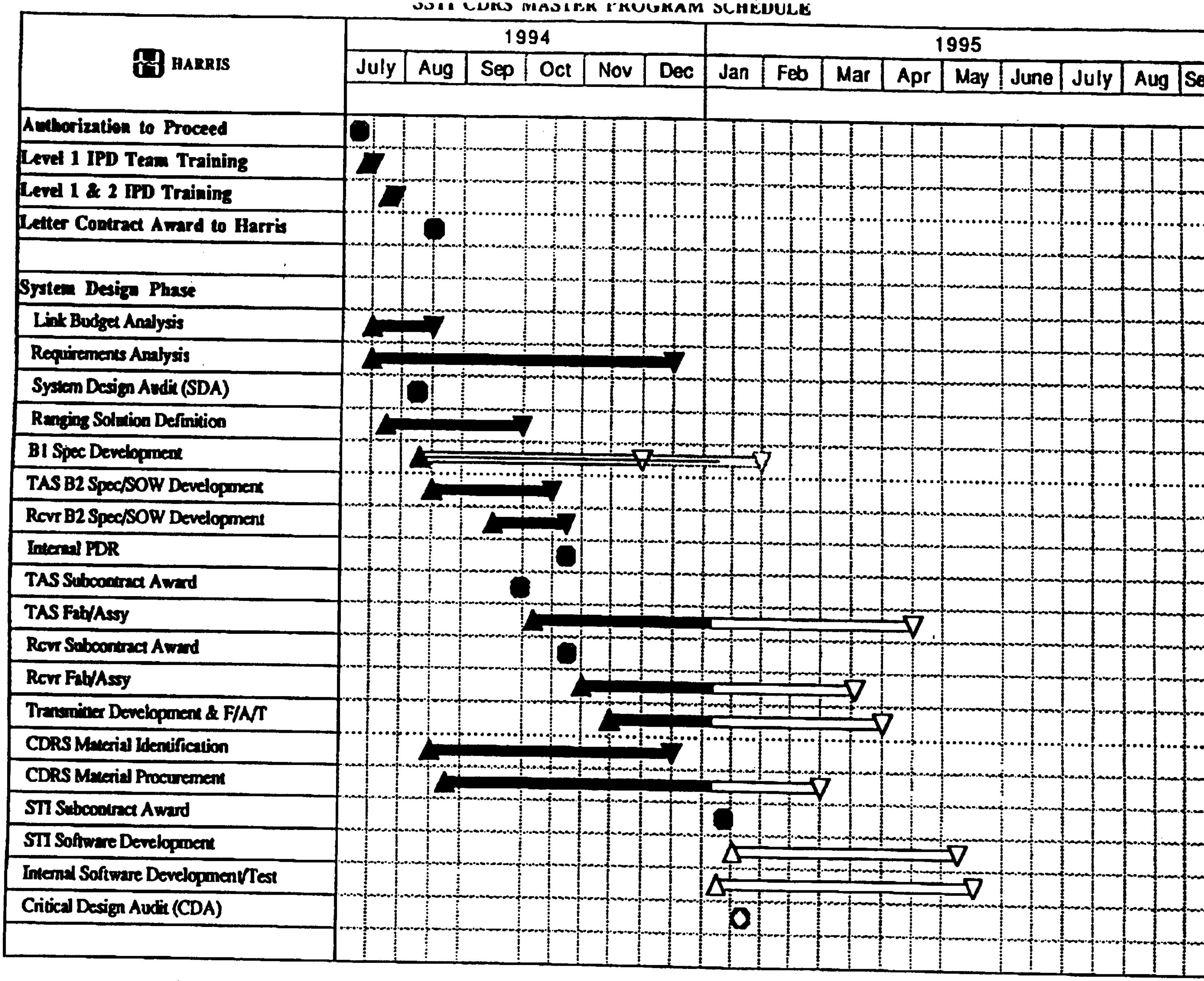
CDRS Computer Software Configuration Design

Development Software:	ANSI C Development Environment
COTS Software Tools:	OS/COMET Satellite Commanding System
	ITAS OMEGA/30 Telemetry Processing System
	SL GSM Graphical Tool Kit
Software Products to Develop :	Viterbi Card Integration
	PCM Simulator Card Integration and Lewis TLM Simulation
	ACU Control/Status for Az, El, RSSI, Time tag
	HP Freq. Counter Control/Status for Doppler Freq.
	Telemetry Parsing Software for Level 0/1A



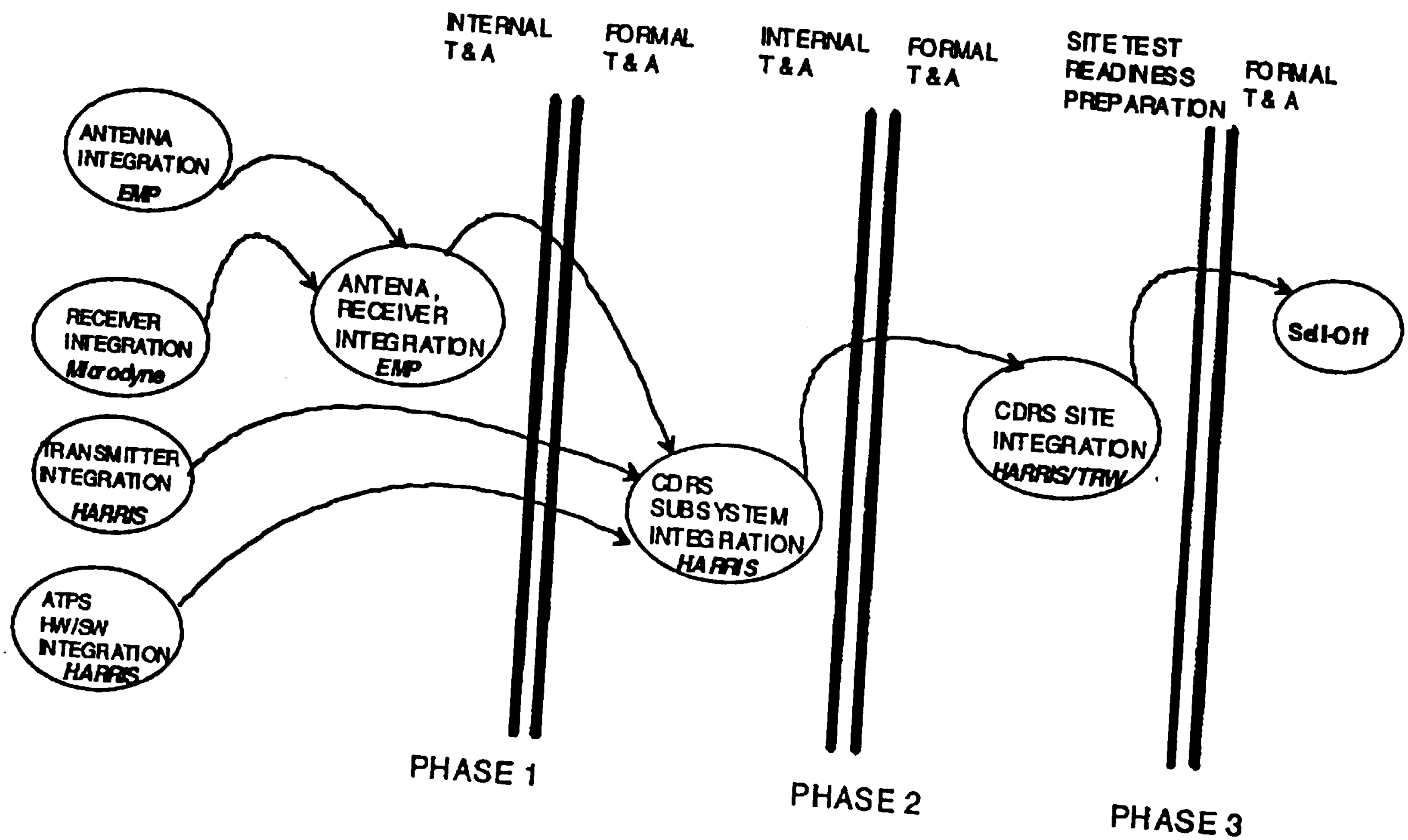
Friday, January 13, 1995

SSTI CDRS MASTER PROGRAM SCHEDULE



Friday, January 13, 1995

Test and Verification



Verification Cross Reference Matrix (VCRM)

Para. No.	Title	Verification Method				Sell-Off Location
		I	A	D	T	
3.1.1	Interface Definition	X				Harris
3.2.1.1	Antenna and RF Characteristics		X			EMP
3.2.1.1.1.1	Manual Pointing			X		TRW
3.2.1.1.1.2	Acquisition and Tracking			X		TRW
3.2.1.1.1.3	Polarization				X	EMP
3.2.1.1.1.4	Sidelobes				X	EMP
3.2.1.1.2.1	Transmit Frequency			X		EMP
3.2.1.1.2.2	RF Phase Modulation and Phase Noise				X	EMP
3.2.1.1.2.3	Transmit EIRP				X	EMP
3.2.1.1.2.4	Transmit Signal Characteristics			X		EMP
3.2.1.1.3.1	Receive Frequency			X		EMP
3.2.1.1.3.2	Implementation Loss				X	Microdyne
3.2.1.1.3.3	Antenna System G/T				X	EMP
3.2.1.1.3.4	Receiver Characteristics			X		Microdyne
3.2.1.1.4	Installation	X				TRW
3.2.1.2.1	Commanding Functions and Characteristics			X		TRW
3.2.1.2.2	Telemetry Functions and Characteristics	X		X		TRW
3.2.1.2.3	Mission Data Processing Functions and Characteristics			X		TRW
3.2.1.2.4	Data Archiving Functions and Characteristics			X		TRW
3.2.1.2.5	Angular and Range Rate Data Generation Functions and Characteristics			X		Harris
3.2.1.2.6	SOCC Communications Functions and Characteristics			X		Harris

Verification Cross Reference Matrix (VCRM) - (Continued)

Para. No.	Title	Verification Method				Sell-Off Location
		I	A	D	T	
3.2.1.2.7	Remote Site Data Communications Functions and Characteristics				X	Harris
3.2.1.2.8	Early Orbit and Check-out Operations			X		Harris
3.2.1.2.9	CDRS Equipment Status Reporting			X		Harris
3.2.2	Physical Characteristics	X				Harris
3.2.3	Reliability and Maintainability	X				Harris
3.2.4	Environmental Conditions	X				Harris
3.2.4.1	Outdoor Equipment	X				Harris
3.2.4.2	Indoor Equipment	X				Harris
3.2.4.3	Shock and Vibration	X				Harris
3.2.5	Transportability	X				Harris
3.3	Design Materials, and Construction	X				Harris
3.3.1	Electromagnetic Radiation	X				Harris
3.3.2	Product Markings	X				Harris
3.3.3	Safety	X				TRW
3.4	Documentation	X				TRW
4.1	Quality Assurance Provisions	X				TRW
4.3.1	Phase 1, CDRS Individual Component Test and Acceptance	X	X	X	X	Vendor, Harris
4.3.2	Phase 2, CDRS Antenna and RF, Baseband Processing In-Plant Integration, Test and Acceptance	X	X	X	X	Harris
4.3.3	Phase 3, CDRS on Site Integration	X	X	X	X	TRW
5.0	Shipping	X				Harris

GROUND SEGMENT
SOCC Design

T. Berman

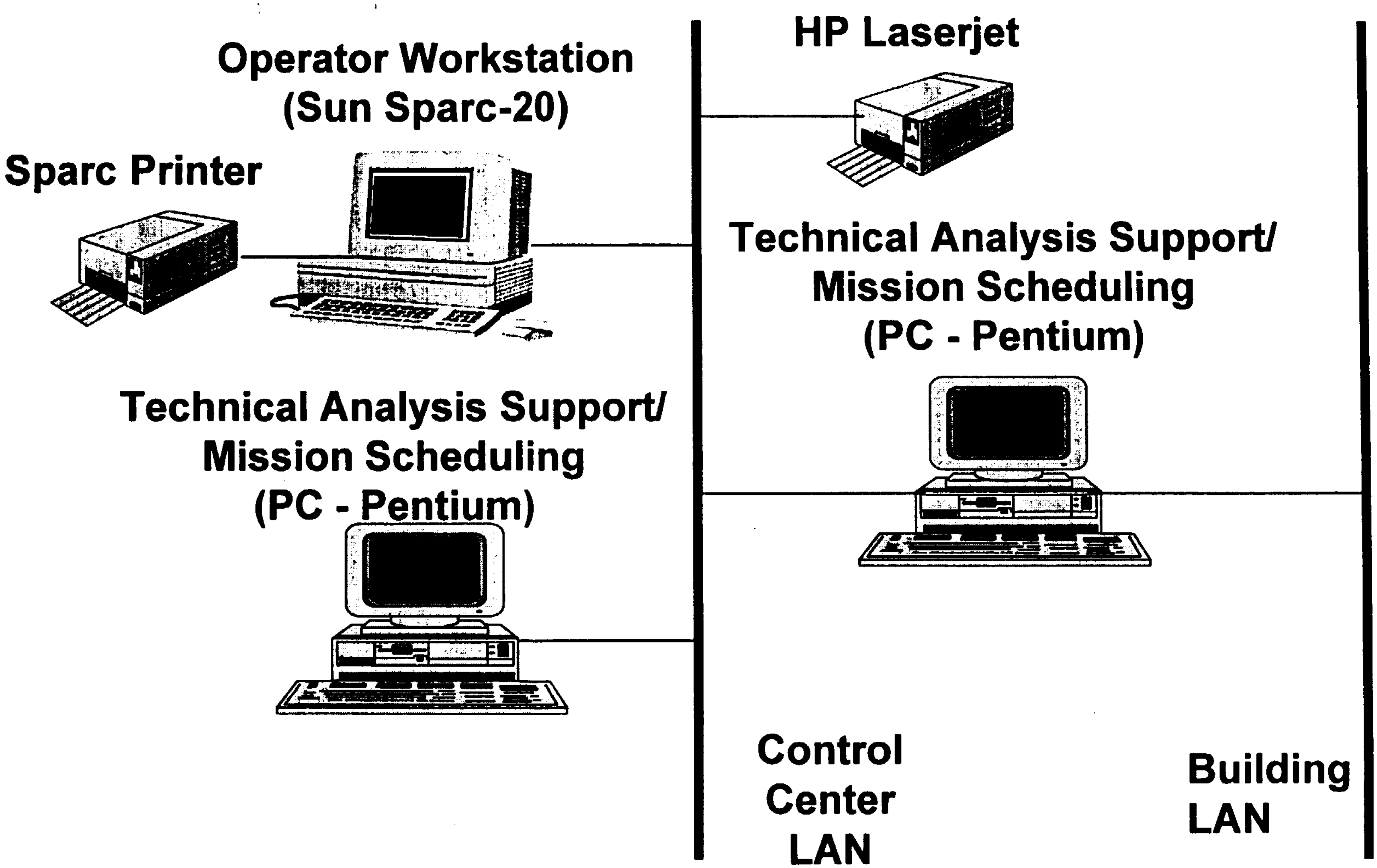
SOCC Functions

- Orbit Determination
- Orbit Propagation
  - Generate Acquisition Data
- Mission Planning
  - Viewing Opportunities
  - Maneuver Planning
  - External Interfaces (Stennis for tasking)
- Scheduling
  - Time Line Generation
  - Pass Plan Generation
- Data Analysis
  - Anomaly Resolution
  - Spacecraft Resource Management
  - Ground Station Performance Statistics
  - Spacecraft Performance Statistics

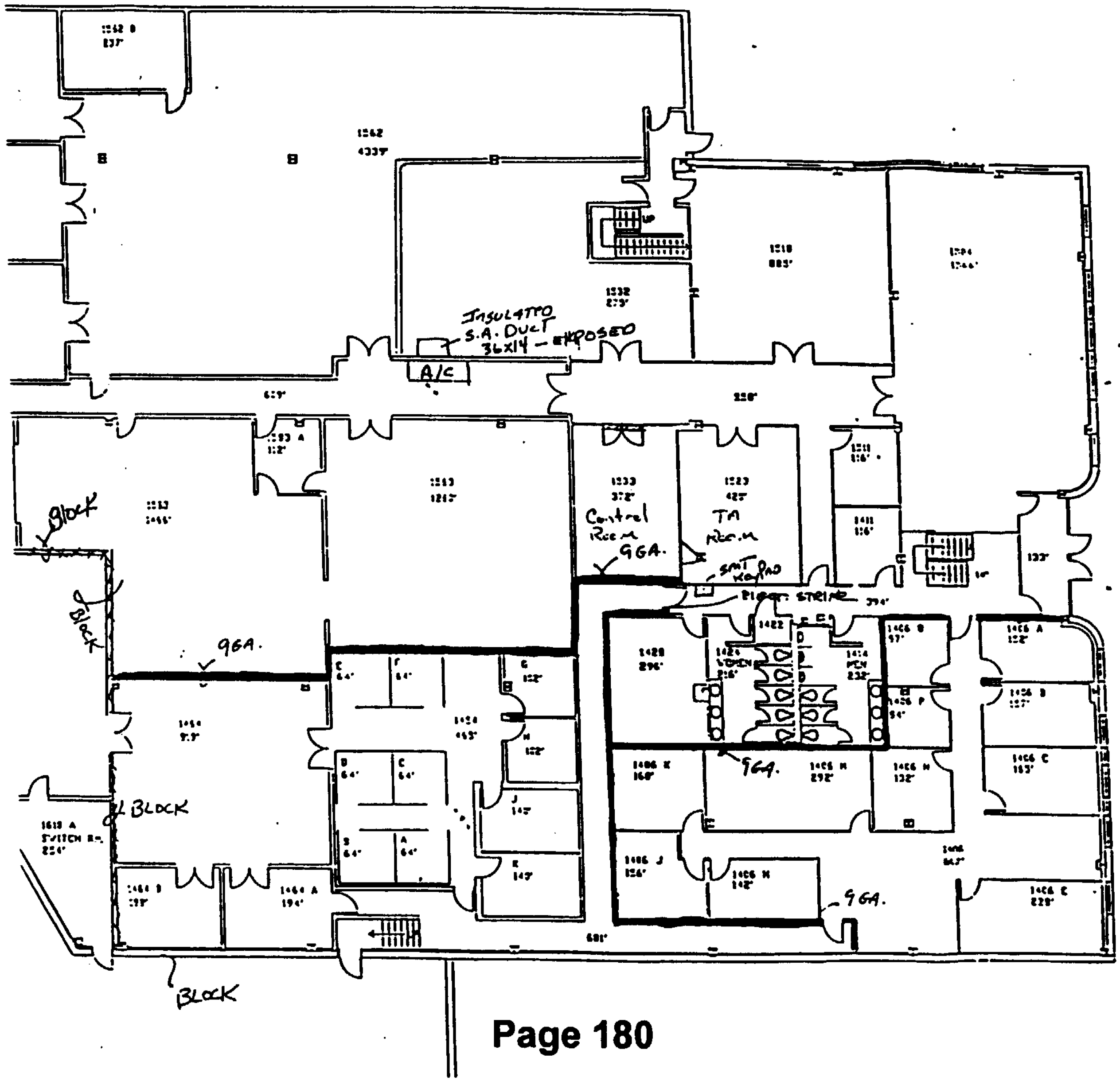
SOCC Software Tools

Area	Tool Support	Platform
Orbit Determination	OASYS	SUN
Orbit Propagation	OASYS mail (tasking requests)	SUN
Mission Planning	OASYS	SUN
Scheduling	Microsoft Word Microsoft Excel	PC
Data Analysis	PV-WAVE Mathematica Microsoft Excel MATLAB	SUN PC

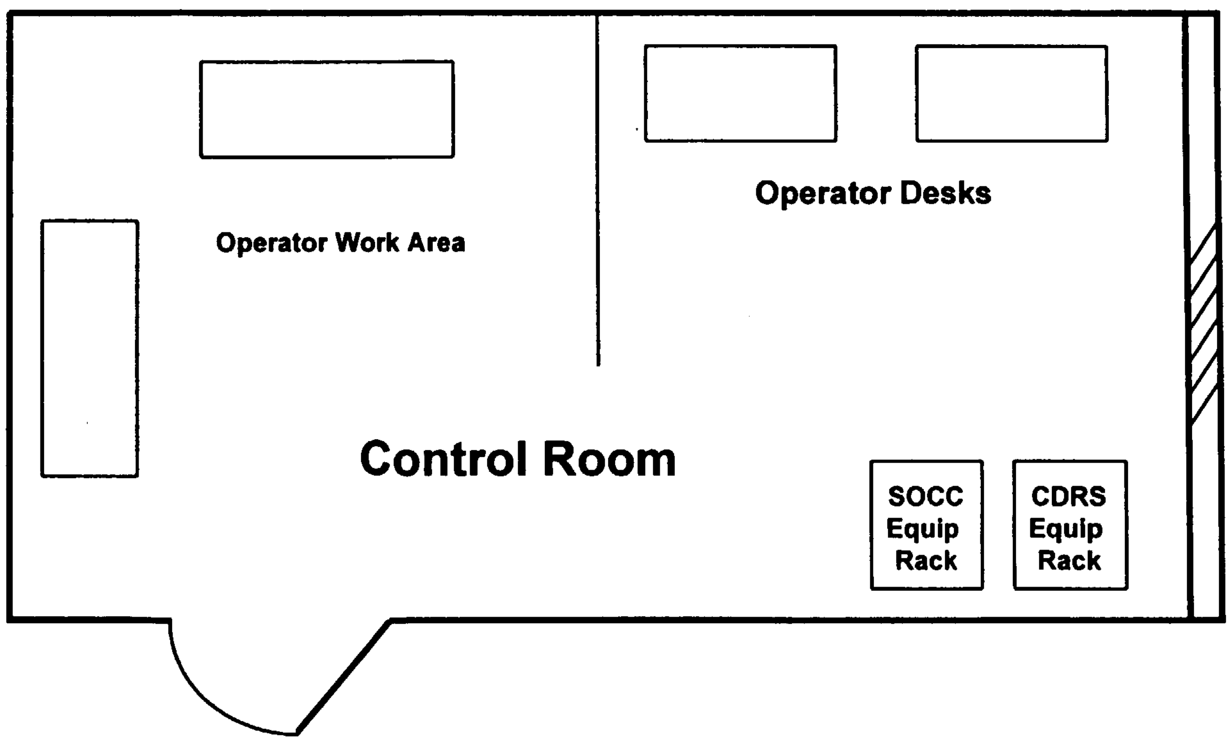
SOCC Overview



TRW/Chantilly Ground Station Location



TRW/Chantilly Ground Station Control Room



SSTI

TRW/Chantilly Facility Modifications

- Antenna Installation
  - Construct antenna support platform on building rooftop
  - Provideelectrical power to rooftop (220V and 110V single phase)
  - Install lighting around platform
  - Install audible alarm (activated from provided relay)
  - Install RF and control cables from control room
- Rooftop Access
  - Install door accessible from building interior
- Control Room
  - Remove existing hallway door and replace with viewing window
  - Install partition door with cipher lock
  - Install ground
  - Install RF Patch Panel
  - Install Phone and Fax Lines

SSTI

SOCC Integration Activities

TRW

Area	Integration Activities
LAN	Wire Hub, Configure PC on Building LAN
Sun and Nighthawk	Set up accounts, Configure LAN SW
PCs	Configure LAN SW
Interface to CDRS	Test file transfers, write scripts to handle file naming where required
OASYS	Set up directory structure, write scripts to handle file naming or selection
Excel, Word	Set up templates for pass plan, timelines, etc.

Verification Cross Reference Matrix

Requirement	Description	Method			
2.1	**Tracking**	I	A	T	D
2.1.010	Receive and Process Initial State Vector				X
2.1.020	Generate/Transmit Pointing Angles to CDRS			X	X
2.1.170	Process and Display Data for OD and Pred.		X	X	X
2.1.180	Select tracking data used for OD				X
2.2	**Planning**				
2.2.010	Receive Predictive Orbit Info from Ext. Source			X	X
2.2.020	Receive tracking data from CDRS				X
2.2.030	Generate Ephemeris/Element Sets		X	X	X
2.2.040	Store and retrieve history of orbital element sets				X
2.2.050	Select orbital element sets for estimated error calculation				X
2.2.060	Calculate estimated error between selected element sets		X	X	
2.2.070	Determine orbit over any specified time interval		X	X	
2.2.080	Propogate Orbit over any specified time interval		X	X	
2.2.090	Generate/Display spacecraft events			X	
2.2.100	Include station-specific obscura in contact determination				X
2.2.110	Generate rise/set, AOS/LOS for ground station contact		X	X	X
2.2.120	Display line, ellipse, and polygon on map overlay				X
2.2.130	Display earth-based map overlay of S/C ground track, FOV,FOR				X
2.2.140	Display FOV,FOR in alphanumeric form				X
2.2.150	Indicate sun eclipse in map overlay				X
2.2.160	Indicate sun eclipse in alphanumeric displays				X
2.2.190	Display in alphanumeric angle of sun/moon relative to S/C				X
2.2.200	Display orbit maneuver, orbit adjusts, station keeping		X	X	X
2.2.220	Calculate attitude params. for terrestrial/celestial HSI targets		X	X	X

SSTI

Verification Cross Reference Matrix

TRW

Requirement	Description	I	A	T	D
2.3	**Scheduling**				
2.3.010	Receive, Generate, Add, Retrieve, Edit, Store, Delete events				X
2.3.020	Manage schedules of tasking req, commands, orb events, etc.				X
2.3.030	Manage tasking requests containing geo coord, time, device, etc				X
2.3.040	Manage in sched. commands, parameters, exec time				X
2.3.050	Manage command sequences in schedule				X
2.3.060	Manage predictable orbital events in schedule				X
2.3.070	Manage discretionary orbital events (e.g., maneuvers) in schedule				X
2.3.080	Manage ground events in schedule				X
2.3.090	Time tag start and stop time of events				X
2.3.100	Display schedules				X
2.3.110	Display schedules for specific time periods/resolutions				X
2.3.120	Display individual events on schedule				X
2.3.130	Concatenate and embed schedules				X
2.3.140	Report tasking requests which are not scheduleable				X
2.3.180	Generate contact plans from schedule				X
2.3.190	Manage contact plans				X
2.3.200	Link contact plans to ground station events				X
2.3.210	Generate time-tagged antenna pointing angles to CDRS			X	X
2.3.220	Estimate initial orbit based on initial state vector			X	X
2.3.230	Create hardcopy of any SOCC display				X
2.3.240	Create softcopy of any SOCC display				X
2.3.250	Display multiple operator interface windows simultaneously				X

Verification Cross Reference Matrix

Requirement	Description	I	A	T	D
5.0.0	Resource Management				
5.1.0	Power	X			X
5.2.0	Momentum	X			X
5.3.0	Maneuver	X			X
5.4.0	Memory	X			X
5.5.0	Propellant	X			X
5.6.0	Thermal	X			X
5.7.0	Orbit	X			X
7.0.0	**Performance**				
7.P.050	Display schedules at rate of 1 per 5 seconds				X
7.P.060	Maintain schedules of up to 1000 events				X
7.P.070	Orbit Determination Accuracy (2KM cross-track, 2KM in, 2KM rad)		X		
7.P.090	Orbit Determination Methods	X			
7.P.100	Orbit Prediction Accuracy		X		
7.P.110	Provide pointing angles and times 14 days prior to contact				X
7.P.120	Determine S/C rise/set to 30 sec accuracy 14 days prior to contact				X
7.P.130	Generate ant angle data 14 days prior to contact				X
7.P.260	Display multiple windows of information simultaneously				X
7.P.270	Event time accuracy (eclipse 1 min., contact 5 sec.)		X		
7.P.280	Display earth-based map overlays (USGS 7.5 min quad, 0.5 lat/lon)				X
7.P.290	Alphanumeric IFOV, FOR accuracy 1KM, 1 sec arc (celestial)				X
7.P.300	Time tag schedule event resolution 1 sec				X
7.P.310	Merge 10 schedules of up to 1000 events in 1 min				X

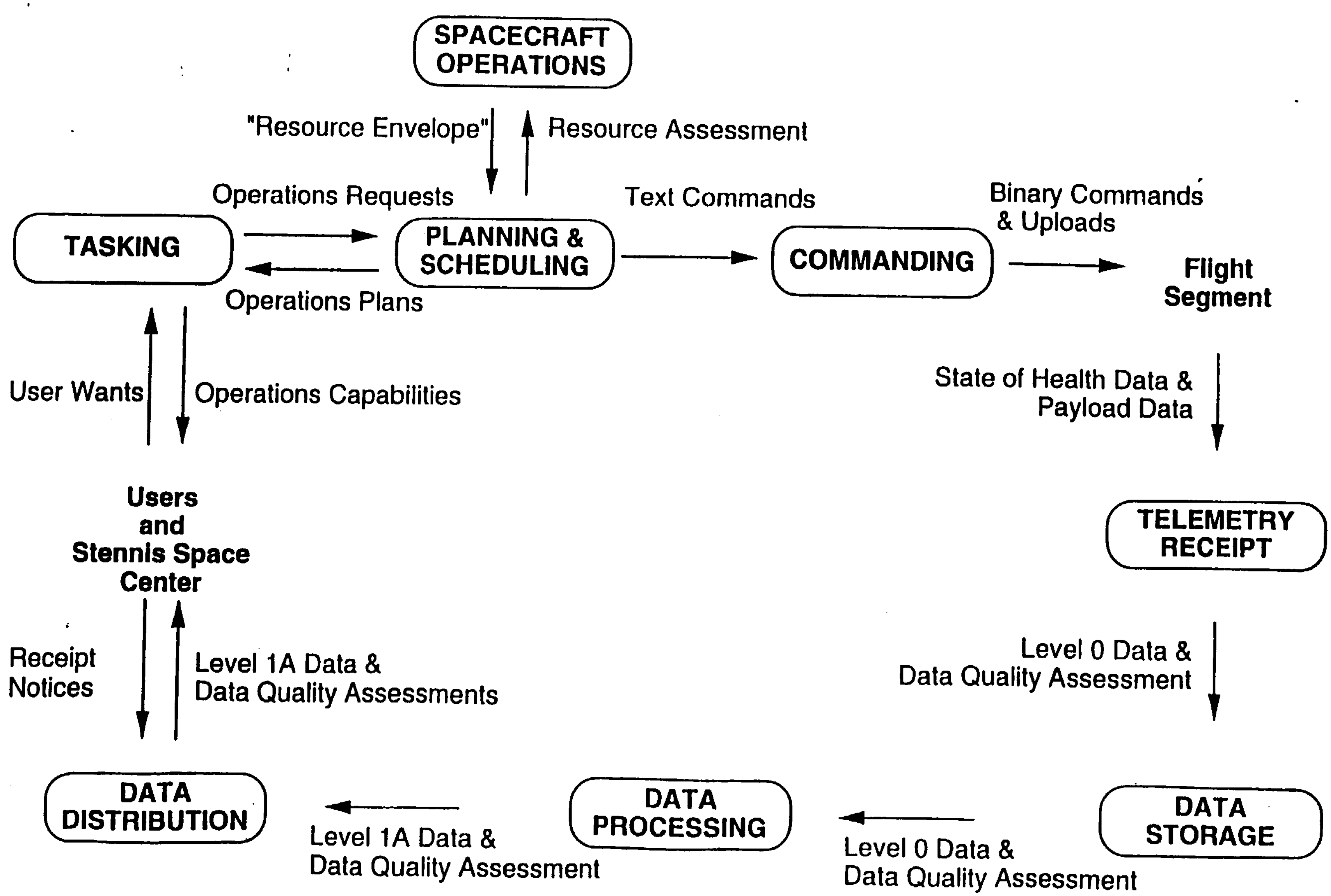
GROUND SEGMENT
Mission Operations

P. Zion

BRIEFING OUTLINE

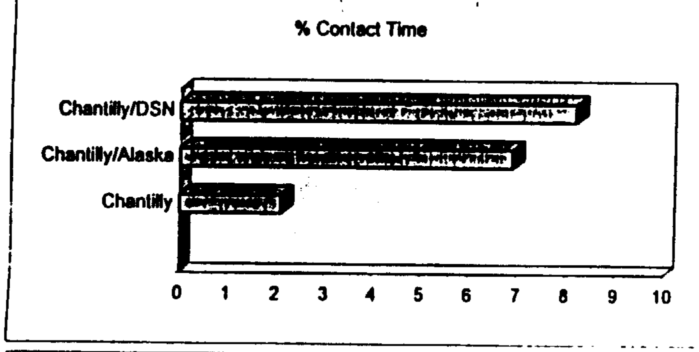
- OPERATIONS CONCEPT SUMMARY
- NASA GROUND NETWORK SUPPORT
- SSTI OPERATIONS: NOMINAL, LEO, CONTINGENCY
- DOCUMENTATION STATUS
- TESTING

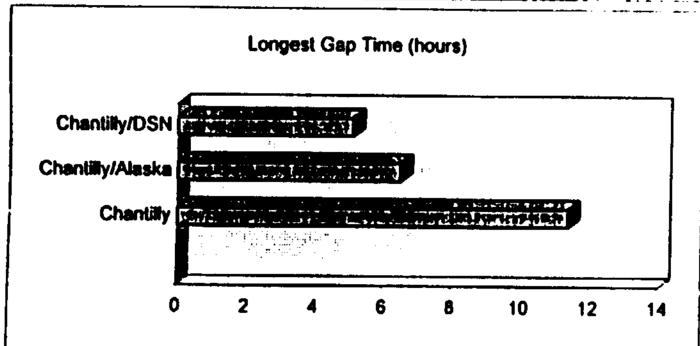
OPERATIONS CONCEPT SUMMARY

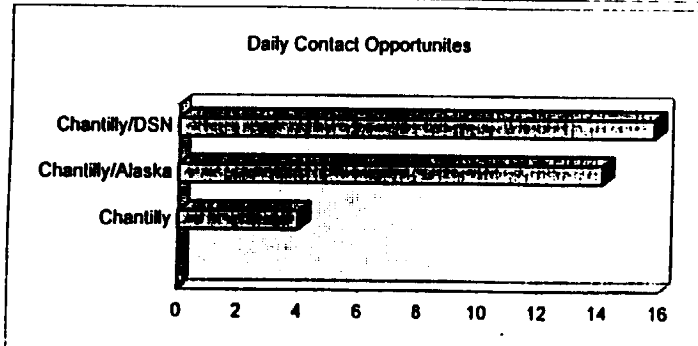


GROUND COVERAGE COMPARISON

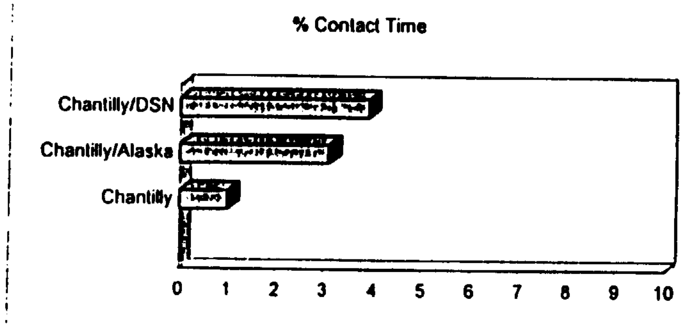
523 km

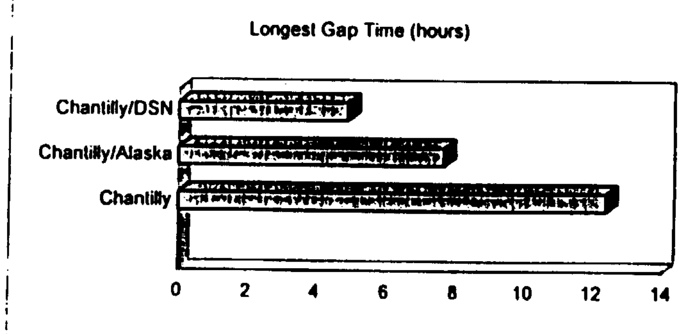


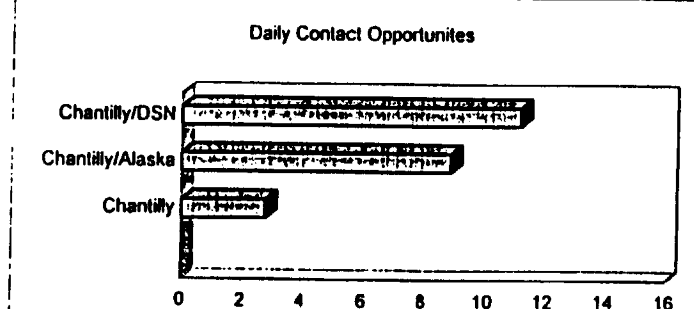




300 km

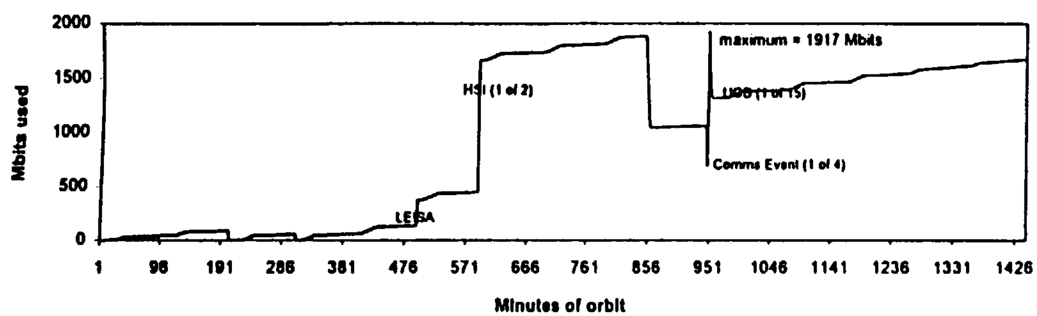




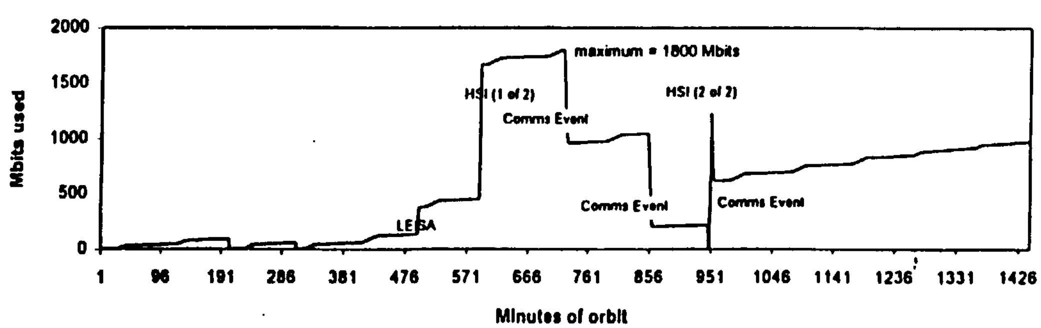


MEMORY UTILIZATION COMPARISON

SSTI Mass Memory Use Scenario - Chantilly Station Only



SSTI Mass Memory Use Scenario - Chantilly Station plus Alaska



- Chantilly meets basic throughput requirement of 1 Gbit/day
- Alaska provides additional downlink capability and scheduling flexibility

MRR PROCESS

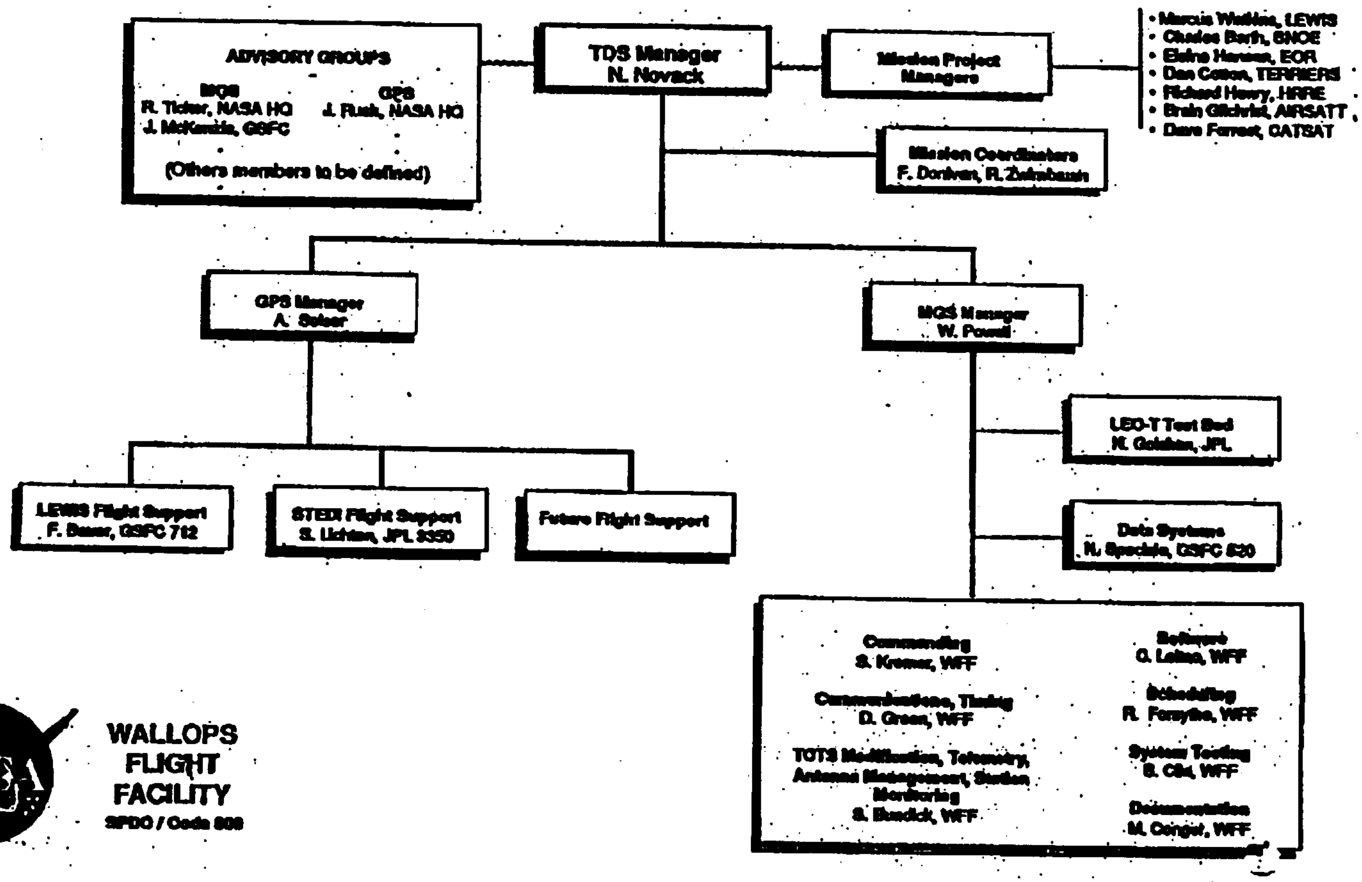
- Final MRR submitted to NASA HQ 1/9/95
- Anticipate WFF designation as lead center
- Requests reflect ops concepts
  - DSN support for LEO* and contingency (forward & return)
  - Alaska station for nominal ops and contingency (forward & return)
  - GSTDN-compatible hardware and protocols
  - High-rate data transfer Alaska<–>Chantilly<–>Stennis
- Tentative frequency assignments by Code O
  - Forward: 2095.172 MHz   Return: 2275.3 MHz   (240/221)
- Technical discussions continue with DSN and MGS**

* LEO = launch and early orbit   **MGS = Mini ground station

NASA GROUND SUPPORT OVERVIEW

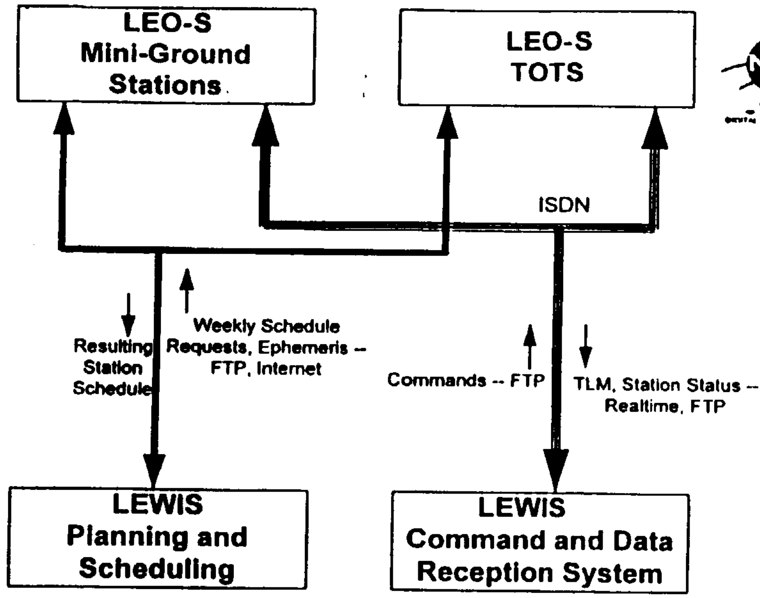
- LEO Period and Contingency
  - DSN tracking support using 2-way Doppler
  - Orbit determination by NASA
  - Tracking data exchange via IIRV
  - Command and SOH telemetry at Chantilly via throughput mode or near-real time mode (delay < 5 seconds)
- Nominal Operations
  - Chantilly station meets mission requirement
  - Alaska option provides benefits:
    - » Enhanced science return
    - » Scheduling flexibility
    - » Additional LEO supports
    - » Contingency supports
  - Command and SOH telemetry at Chantilly via Alaska
  - Science data returned to Chantilly by file transfer

NASA MGS ORGANIZATION



WALLOPS
FLIGHT
FACILITY
SPDO / Code 808

ALASKA-CHANTILLY OPS CONCEPT



Scheduling
- Resolve LEO-S conflicts among users
- Schedule requests desired one week in advance
- WFF/LEO-S final arbiter of conflicts

Pass Sequence
- T - 5 min: ISDN connection established
- T - 2 min: Antenna pointed at rise point
- T - 1 min: U/L acquisition begins
- Track period: Real-time link to user, tracking data to FDF
- Post-pass: ISDN line drops within 1 minute of set
- User transfers data to POCC via FTP

Predicts
- Daily exchange of ephemeris data

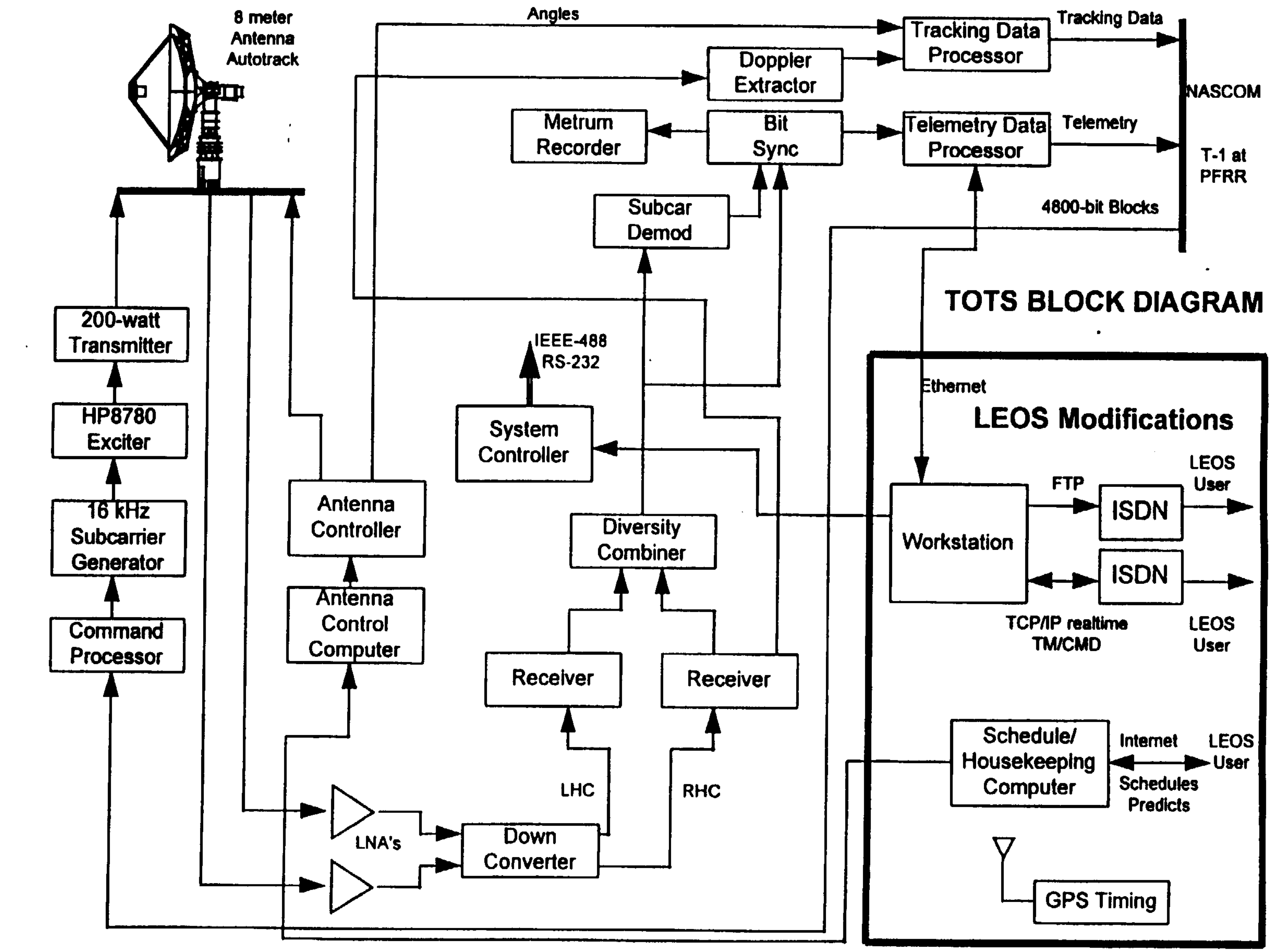
TOTS = Transportable Orbital Tracking System

- Two systems f ielded by WFF
- Third deliverable late CY95
- 8m S-band xmit/rcv autotrack
- 22 dB/K G/T
- 5 Mbit/s channel
- IIRV or NORAD el set
- NASCOM 4800-bit block interface
- Unmanned operation

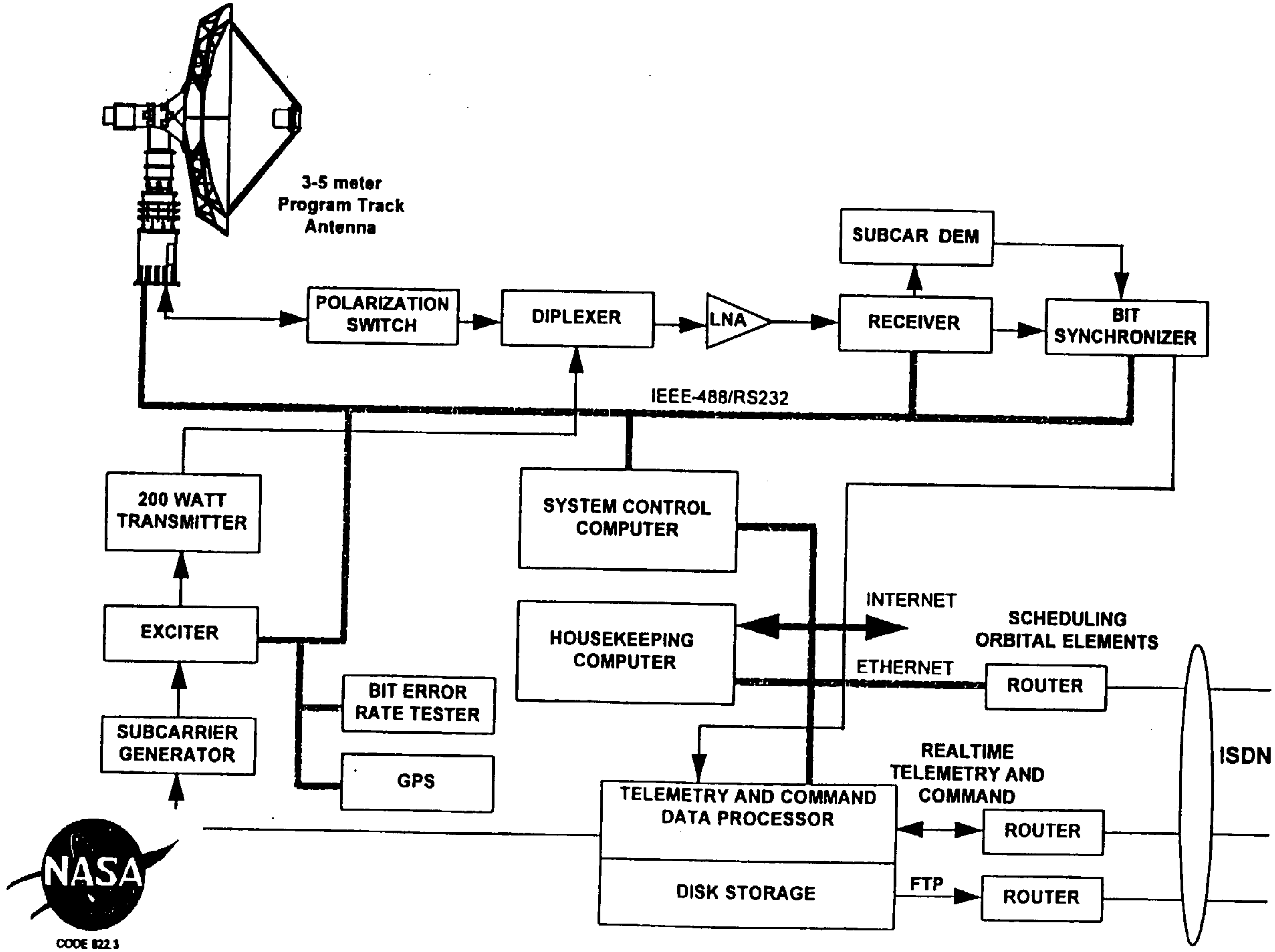
LEO-S = Low Earth Orbiter Station

- TOTS follow-on
- First system deliverable mid CY96
- 3-5m S-band xmit/rcv program track
- 13 dB/K G/T
- 2.3 Mbit/s channel
- IIRV or NORAD el set
- "Real-time" TCP/IP C&T service
- Post-pass data via FTP
- Direct user interface (multi-user)
- Unmanned operation

TOTS w/LEO-S AUGMENTATION



STANDALONE LEO-S DESIGN



CODE 822.3
RF TRACKING AND
DIGITAL SYSTEMS SECTION

TOTS/LEO-S SCHEDULE

	1995												1996						
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
TOTS/LEO DEVELOPMENT																			
TOTS/LEO-S Interface Spec		◇																	
LEO-S Spec		◇																	
LEO-S Contract Award							◇												
TOTS/LEO-S Interface										◇									
TOTS/LEO-S Interface Test											◇								
TOTS/LEO-S IOC												◇							
LEO-S Delivery and Test													◇						
LEO-S IOC														◇					
TOTS/LEWIS Compat. Test															◇				
LEWIS INTERFACE																			
ICD		◇																	
Scheduling Approach			◇																
Loading Study - TOTS		◇																	
Ops Concept Definition - TOTS	◇																		
Loading Study - LEO-S												◇							
Ops Concept Definition - LEO-S			◇																

- TOTS ready for Lewis launch
- LEO-S lags Lewis launch by 3-6 months
- LEO-S swap-in will be transparent to Lewis
- Standalone LEO-S subject to test
- LEO-S swap-in not mission critical

DSN UTILIZATION - STATUS

- Began DSN technical interchange 1/95
- Tabletop review of Lewis MRR
- Received sample documents
  - DSN -to-Flight Project Interface Handbook (JPL 810-5)
  - DSN-to-CSA Interface Control Document (Radarsat)
  - ADEOS DMR
  - FAST DSN Compatibility Test Plan
- Planning Lewis-to-DSN documentation tree

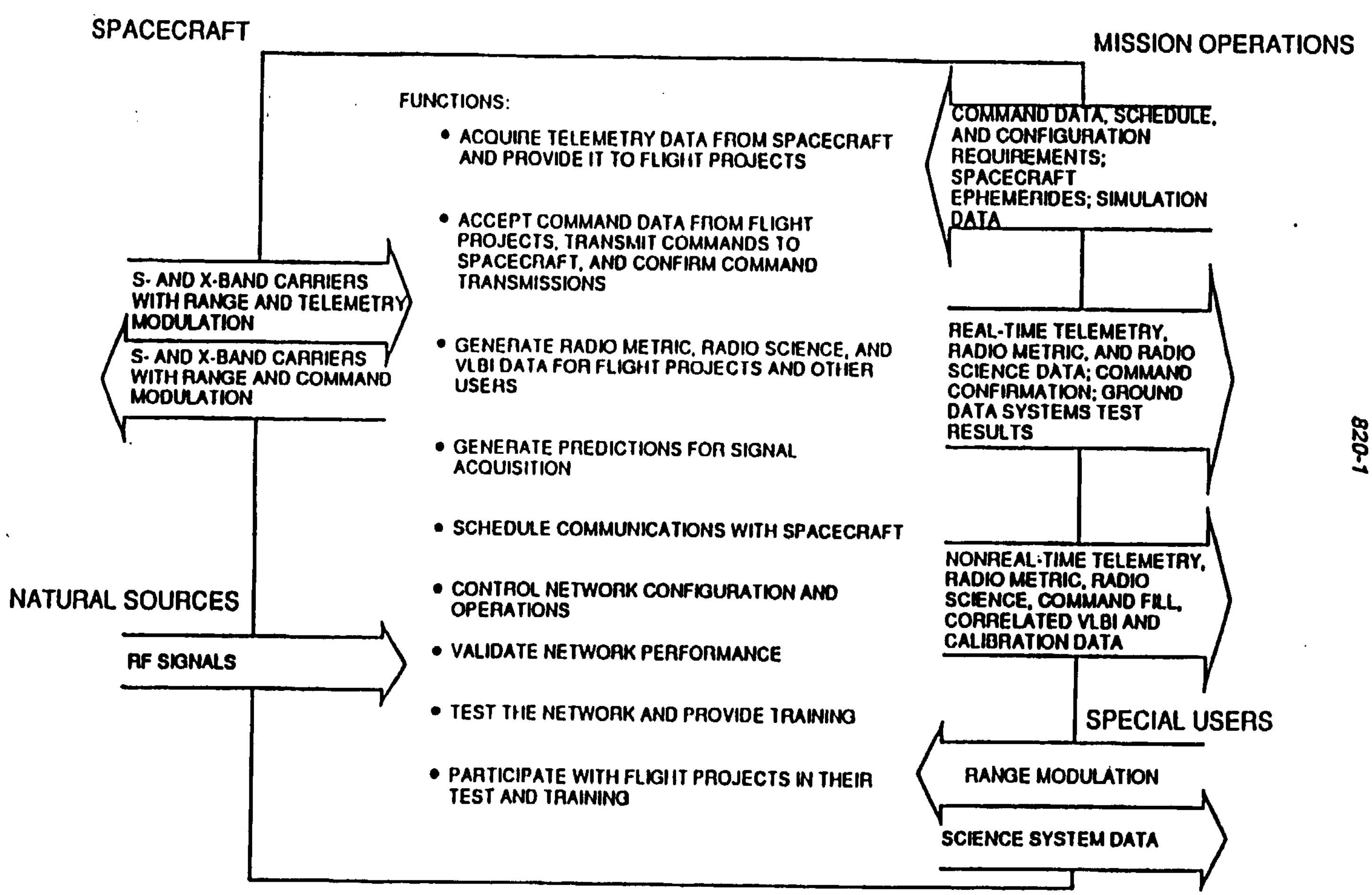


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Figure 3-1. Functions of the Deep Space Network

OPERATIONS

- NOMINAL
- LEO
- CONTINGENCY

Week Starting	Image No.	Sunday Orbit No.	Sunday Instrument/Bands/Length/Site	Monday Orbit No.	Monday Instrument/Bands/Length/Site	Tuesd. Orbit No.	Tuesd. Instrument/Bands/Length/Site	Wednesday Orbit No.	Wednesday Instrument/Bands/Length/Site	Thursday Orbit No.	Thursday Instrument/Bands/Length/Site	Orbit No.	Instrument
2[illegible]-Jun-[illegible]7			GSFC Antartic Ice Flows LEISA/256/77/ARC		Purdue #2 HSI/384/7/B		Purdue #3 HSI/384/7/B		Falcon HSI/384/70/B		GSFC Sahara Desert LEISA/256/77/F		LEI
	2		/ / /		/ / /		/ / /		/ / /		/ / /		
	3		/ / /		/ / /		/ / /		/ / /		/ / /		
2[illegible]-Jun-[illegible]7			/ / /		Purdue #2 HSI/384/7/B		/ / /		Falcon HSI/384/70/B		/ / /		
	2		/ / /		/ / /		/ / /		/ / /		/ / /		
	3		/ / /		/ / /		/ / /		/ / /		/ / /		
6-Jul-[illegible]7			Purdue #1 HSI/384/7/B		Hampton University HSI/384/70/B		/ / /		UC Santa Barbara Jeff Dozier Sierra Nevada		GSFC White Sands LEISA/256/77/F		
	2		/ / /		U. of Alaska Augustine Volcano HSI/384/20/G		/ / /		U. of Alaska Katmai Region HSI/384/30/G		U. of Alaska Aniakchak Caldera HSI/384/30/G		
	3		/ / /		/ / /		/ / /		/ / /		/ / /		
13-Jul-[illegible]7			Purdue #1 HSI/384/7/B		GSFC Amazon Coast #1 LEISA/256/77/ARC		Purdue #3 HSI/384/7/B		/ / /		/ /		
	2		/ / /		U. of Alaska Augustine Volcano HSI/384/20/G		/ / /		U. of Alaska Katmai Region HSI/384/30/G		U. of Alas Aniakchak C HSI/384/		
	3		/ / /		/ / /		/ / /		/ / /		/ /		
2[illegible]-Jul-[illegible]7			Purdue #1 HSI/384/7/B		GSFC Amazon Coast #2 LEISA/256/77/ARC		Purdue #3 HSI/384/7/B		Purdue #4 HSI/384/7/B		/		
	2		/ / /		U. of Alaska Augustine Volcano HSI/384/20/G		/ / /		U. of Alaska Katmai Region HSI/384/30/G		U. o Aniakc HSI/		

- Harold Jesse study
- Polled science, applications, education users
- Extrapolated from airborne study
- Used realistic mission constraints
- Populated 1 year of observation time
- Includes application domain (geology, soils, instrument calibration, etc.)

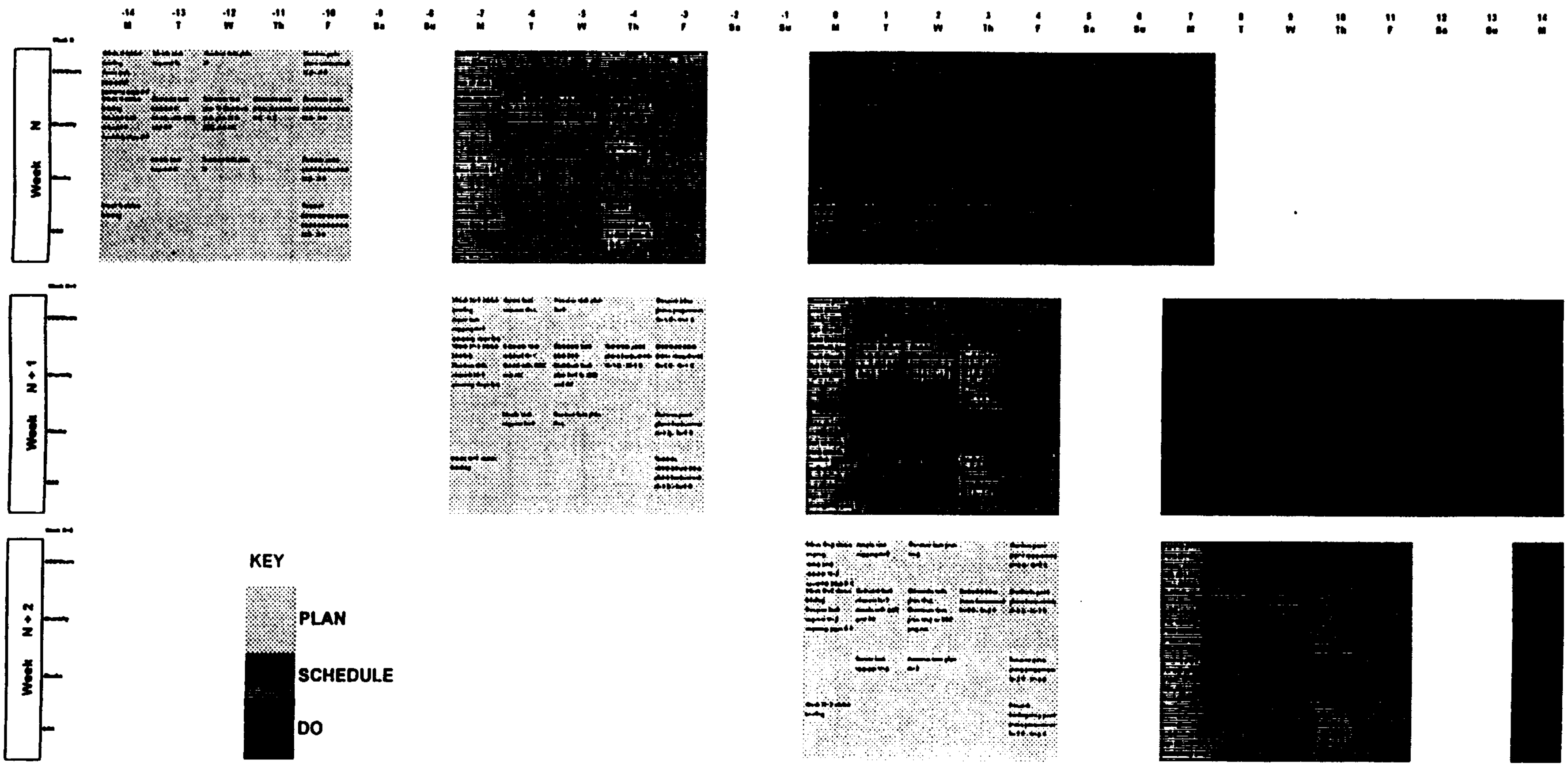
ONE WEEK OF HSI OBSERVATIONS

Station #01 Cambridge, MA						8/16/96 14:51:34	8/17/96 14:39:32	
Station #02 White Mt, NH						8/16/96 14:51:58	8/17/96 14:39:57	
Station #03 Chesapeake Bay, MD				8/14/96 15:14:47	8/15/96 15:02:46			
Station #04 Newport News, VA				8/14/96 15:14:07				
Station #05 Washington, DC				8/14/96 15:14:36				
Station #06 Durham, NC			8/13/96 15:25:54					
Station #07 Cape Canaveral, FL		8/12/96 15:35:53						
Station #08 Savannah R., GA		8/12/96 15:36:49						
Station #09 Bainbridge, GA	8/11/96 15:48:31							
Station #10 Indiana/Ohio Border	8/11/96 15:50:56	8/12/96 15:38:55						
Station #11 Pundo, IN	8/11/96 15:51:04							
Station #12 Northern Mississippi							8/17/96 16:12:38	8/18/96 16:00:37
Station #13 Bay St. Louis, MS							8/17/96 16:11:35	
Station #14 St. Louis, MO							8/17/96 16:13:44	8/18/96 16:01:43
Station #15 Baton Rouge, LA						8/16/96 16:23:34	8/17/96 16:11:33	
Station #16 Eastern Texas					8/15/96 16:36:13	8/16/96 16:24:12		
Station #17 Houston, TX					8/15/96 16:35:25			
Station #18 Chickasha, OK				8/14/96 16:48:48	8/15/96 16:36:47			
Station #19 Kansas				8/14/96 16:49:38				
Station #20 Rocky Flats, CO			8/13/96 17:01:49	8/14/96 16:49:49				

Station #21 Boulder, CO		8/12/96 17:14:09	8/13/96 17:02:08					
Station #22 White Sands, NM	8/11/96 17:24:18	8/12/96 17:12:22						
Station #23 Tucson, AZ								8/18/96 17:35:15
Station #24 Scottsdale, AZ								8/18/96 17:35:33
Station #25 Colorado R., AZ							8/17/96 17:47:26	
Station #26 Site #2, NV							8/17/96 17:48:18	
Station #27 Site #1, NV							8/17/96 17:49:11	
Station #28 San Diego, CA						8/16/96 17:59:26		
Station #29 Edwards, CA						8/16/96 17:59:55		
Station #30 Los Angeles, CA						8/16/96 17:59:43		
Station #31 La Grande, OR						8/16/96 18:02:40	8/17/96 17:50:40	
Station #32 Mammoth Lakes, CA						8/16/96 18:00:41		
Station #33 Mono Lake, CA						8/16/96 18:00:46		
Station #34 Hanford, WA						8/16/96 18:03:05	8/17/96 17:51:04	
Station #35 Owens Valley, CA					8/15/96 18:12:55	8/16/96 18:00:54		
Station #36 Monterey, CA					8/15/96 18:12:27			
Station #37 San Francisco, CA				8/14/96 18:24:38	8/15/96 18:12:42			
Station #38 Central Valley, CA					8/15/96 18:13:30			
Station #39 Alaska						8/16/96 19:44:15	8/17/96 19:32:16	8/18/96 19:20:13
Station #40 Honolulu, HI							8/17/96 20:54:44	8/18/96 20:42:43

- 40 sites identified for HSI observations
- Chart lists visibilities with elevation > 68°
- Nominally only one site per pass can be acquired
- Cycle repeats weekly

SSTI OPERATIONS CYCLE



SSTI OPERATIONS CYCLE

	0	1	2	3	4	5	6	7
	M	T	W	Th	F	Sa	Su	M
Week N								
SSC/Users		Receive and acknowledge data from passes N.0	Receive and acknowledge data from passes N.1	Receive and acknowledge data from passes N.2	Receive and acknowledge data from passes N.3	Receive and acknowledge data from passes N.4	Receive and acknowledge data from passes N.5	Receive and acknowledge data from passes N.6
Chantilly	Implement pass plans N.0; Day N.0 reports completed;	Implement pass plans N.1; Day N.1 reports completed;	Implement pass plans N.2; Day N.2 reports completed;	Implement pass plans N.3; Day N.3 reports completed;	Implement pass plans N.4; Day N.4 reports completed;	Implement pass plans N.5; Day N.5 reports completed;	Implement pass plans N.6; Day N.6 reports completed;	
Alaska	Implement pass plans N.0; Transfer science and tracking data from passes N.0 to Chantilly	Implement pass plans N.1; Transfer science and tracking data from passes N.1 to Chantilly	Implement pass plans N.2; Transfer science and tracking data from passes N.2 to Chantilly	Implement pass plans N.3; Transfer science and tracking data from passes N.3 to Chantilly	Implement pass plans N.4; Transfer science and tracking data from passes N.4 to Chantilly	Implement pass plans N.5; Transfer science and tracking data from passes N.5 to Chantilly	Implement pass plans N.6; Transfer science and tracking data from passes N.6 to Chantilly	
DSN	Implement contingency pass plans N.0; Transfer tracking data from passes N.0 to Chantilly	Implement contingency pass plans N.1; Transfer tracking data from passes N.1 to Chantilly	Implement contingency pass plans N.2; Transfer tracking data from passes N.2 to Chantilly	Implement contingency pass plans N.3; Transfer tracking data from passes N.3 to Chantilly	Implement contingency pass plans N.4; Transfer tracking data from passes N.4 to Chantilly	Implement contingency pass plans N.5; Transfer tracking data from passes N.5 to Chantilly	Implement contingency pass plans N.6; Transfer tracking data from passes N.6 to Chantilly	
Week N+1								
SSC/Users	Receive pass plans (timed) N+1.0 - N+1.6; Sign off pass plans (timed) N+1.0 - N+1.6							
Chantilly	Distribute pass plans (timed) N+1.0 - N+1.6; Sign off pass plans (timed) N+1.0 - N+1.6	Create command loads for pass plans N+1.0 - N+1.6	Approve command loads for pass plans N+1.0 - N+1.6	Approve command loads for pass plans N+1.0 - N+1.6; Distribute contingency command loads for pass plans N+1.0 - N+1.6				Implement pass plans N+1.0; Day N+1.0 reports completed;
Alaska	Receive pass plans (timed) N+1.0 - N+1.6; Sign off pass plans (timed) N+1.0 - N+1.6							Implement pass plans N+1.0; Transfer science and tracking data from passes N+1.0 to Chantilly
DSN	Receive contingency pass plans (timed) N+1.0 - N+1.6; Sign off contingency pass plans (timed) N+1.0 - N+1.6							Implement contingency pass plans N+1.0; Transfer tracking data from passes N+1.0 to Chantilly
Week N+2								
SSC/Users	Week N+2 status briefing; Issue task request N+2 covering days 0-6	Iterate task request N+2	Receive task plan N+2		Receive pass plans (sequence) N+2.0 - N+2.6			Receive pass plans (timed) N+2.0 - N+2.6; Sign off pass plans (timed) N+2.0 - N+2.6
Chantilly	Week N+2 status briefing; Receive task request N+2 covering days 0-6	Evaluate task request N+2; Iterate with SSC and AK	Generate task plan N+2; Distribute task plan N+2 to SSC and AK	Generate pass plans (sequence) N+2.0 - N+2.6	Distribute pass plans (sequence) N+2.0 - N+2.6			Distribute pass plans (timed) N+2.0 - N+2.6; Sign off pass plans (timed) N+2.0 - N+2.6
Alaska		Iterate task request N+2	Receive task plan N+2		Receive pass plans (sequence) N+2.0 - N+2.6			Receive pass plans (timed) N+2.0 - N+2.6; Sign off pass plans (timed) N+2.0 - N+2.6
DSN	Week N+2 status briefing				Receive contingency pass plans (sequence) N+2.0 - N+2.6			Receive contingency pass plans (timed) N+2.0 - N+2.6; Sign off contingency pass plans (timed) N+2.0 - N+2.6

A DAY IN THE LIFE OF SSTI

ASCE: On at "midnight" of Rev 1 for 5 minutes
ASSCFE: On at "noon" and midnight of all Revs
Data Compression: Not used
GPS, GEM, MOCK, REM: On for the entire day
HSI: Imaging at 9:49 (Alaska) and 15:49(Georgia) as follows:

- T - 10: Channel selection and configuration
- T - 5: Begin roll
- T - 3: End roll
- T- 2: End settling time
- T - 2: Begin calibration
- T - 30 seconds: End calibration
- T - 8 seconds: Door open
- T - 0: Begin image take
- T + 3 seconds: End image take
- T + 8 seconds: Door closed
- T + 10 seconds: Begin unroll
- T + 10 seconds: Begin calibration
- T + 2 : End calibration
- T + 2: HSI to standby
- T + 3: End unroll, settling complete

LEISA: Observes Alaska at 8:14 as follows:

- T - 5: Begin yaw
- T - 3: End yaw
- T - 2: End settling time
- T - 1: OPA positioning
- T - 0: Begin image take
- T + 10 sec: End image take
- T + 1 min: Begin unyaw
- T + 2 min: End unyaw

MMCHS: On for 1 hour (21:19 - 22:19)
MSRW: 5 minutes of special ops (1:36 - 1:41)
UCB: Observes each eclipse as follows:

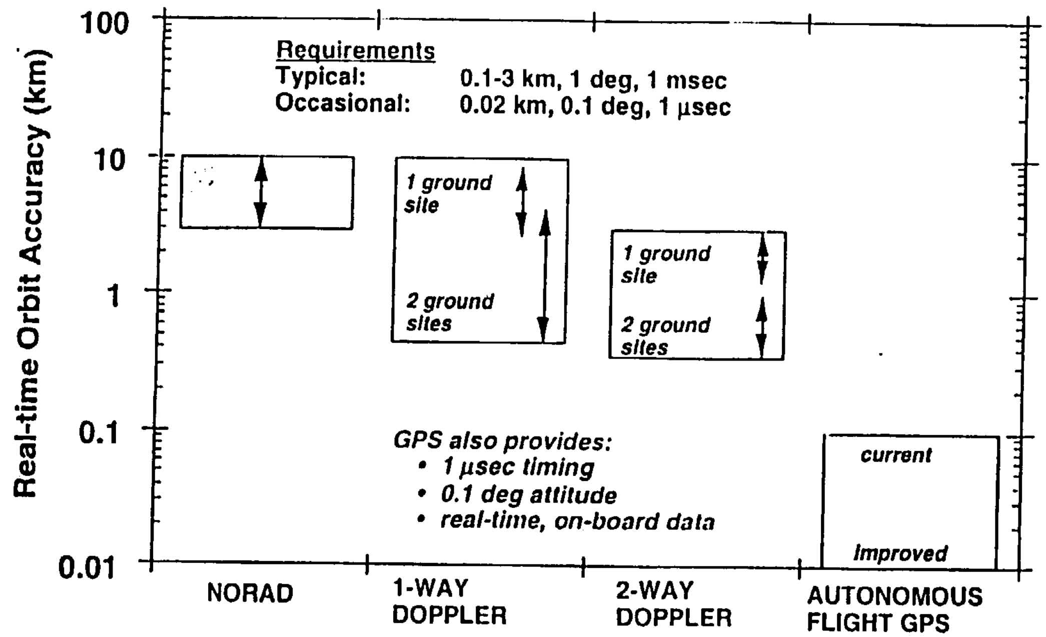
- Eclipse entry (EE): Begin maneuver
- EE + 5: End maneuver
- EE + 5: Begin observation
- SAA entry - 5: End observation
- SAA exit + 5: Begin observation
- Eclipse exit (EX) - 5: End observation
- Eclipse exit: Begin demaneuver
- EX + 5: End demaneuver

WFOVST: On for 2 orbits (22:11 - 23: 59)

Comms: 3:32 - 3:41, 5:07 - 5:14, 14:13 - 14:20, 15:46 - 15:55. 5 degree elevation used.

Times are in UTC

ORBIT DETERMINATION



• *GPS strongest candidate for automating tracking/nav functions*

Autonomous Command, Tracking, and In-Orbit Navigation (ACTION) Project

• HSI targeting requirement places stricter requirement on orbit prediction than does acquisition

• Ground-based orbit determination alone is inadequate for HSI targeting requirement

SSTI

HSI ACQUISITION TIMELINE

TRW

Time	Event
T - 14 days	Tasking request to Chantilly
T - 13 days	Analyst determines contact opportunity using OASYS
T - 12 days	Task plan returned to SSC
T - 7 days	Rough (~1 min) timed HSI command sequence generated. Includes roll time, predicted roll and ECI position at T - 1 min, and HSI commands
T - 6 hours	Command sequence uplinked to spacecraft and verified
T - 10 min	Command pops off schedule to HSI for channel select and configure
T - 5 min	Begin roll to predict
T - 3 min	End roll to predict
T - 2 min	Begin calibration
T - 1 min	Command pops off schedule to ACS
T - 45 sec	ACS roll correction complete. ACS image take time calculated.
T - 30 sec	Calibration ends
T - 8 sec*	HSI door open in response to ACS generated command
T = 0*	Image take begins

* Image take start time based on ACS calculation, not ground estimate.

SSTI

PRE-PASS ACTIVITY

- **Pre-pass**
  - Tasking group interactions
  - Orbit analysis, target and contact prediction
  - Command preparation and checking
  - Command sequencing
  - Station configuration
  - Ground network communications

IN-PASS AND POST-PASS ACTIVITY

- **In-pass**
  - Verify AOS, SOH telemetry present
  - Monitor SOH for duration of pass
  - Issue commands as required (immediate and scheduled)
  - Issue code uploads as required
  - "Possible" commands are ready for issuance
  - Receive data
  - Command spacecraft transmitter off, verify LOS
- **Post-pass**
  - Deconfigure as required
  - Orbit reconstruction
  - SOH telemetry will be available on LAN
  - Begin preparation of data records for SSC
  - Logbook
  - Post-pass conference as required

NOMINAL OPERATIONS ASSUMPTIONS

- HSI observes only the 40 U.S. sites
- HSI observes < 3 * 385 channel-seconds / rev
- 2 Gbit memory limit
- 24-hour data delivery time to Stennis
- Data sorted and sequenced for Stennis
- T1 equivalent between Stennis and Chantilly
- Observations (mostly) planned 14 days ahead
- Experiment operations as per FORD
- 30 days LEO + 335 days Nominal Operations
- 10 operations shifts/week, 2 persons/shift

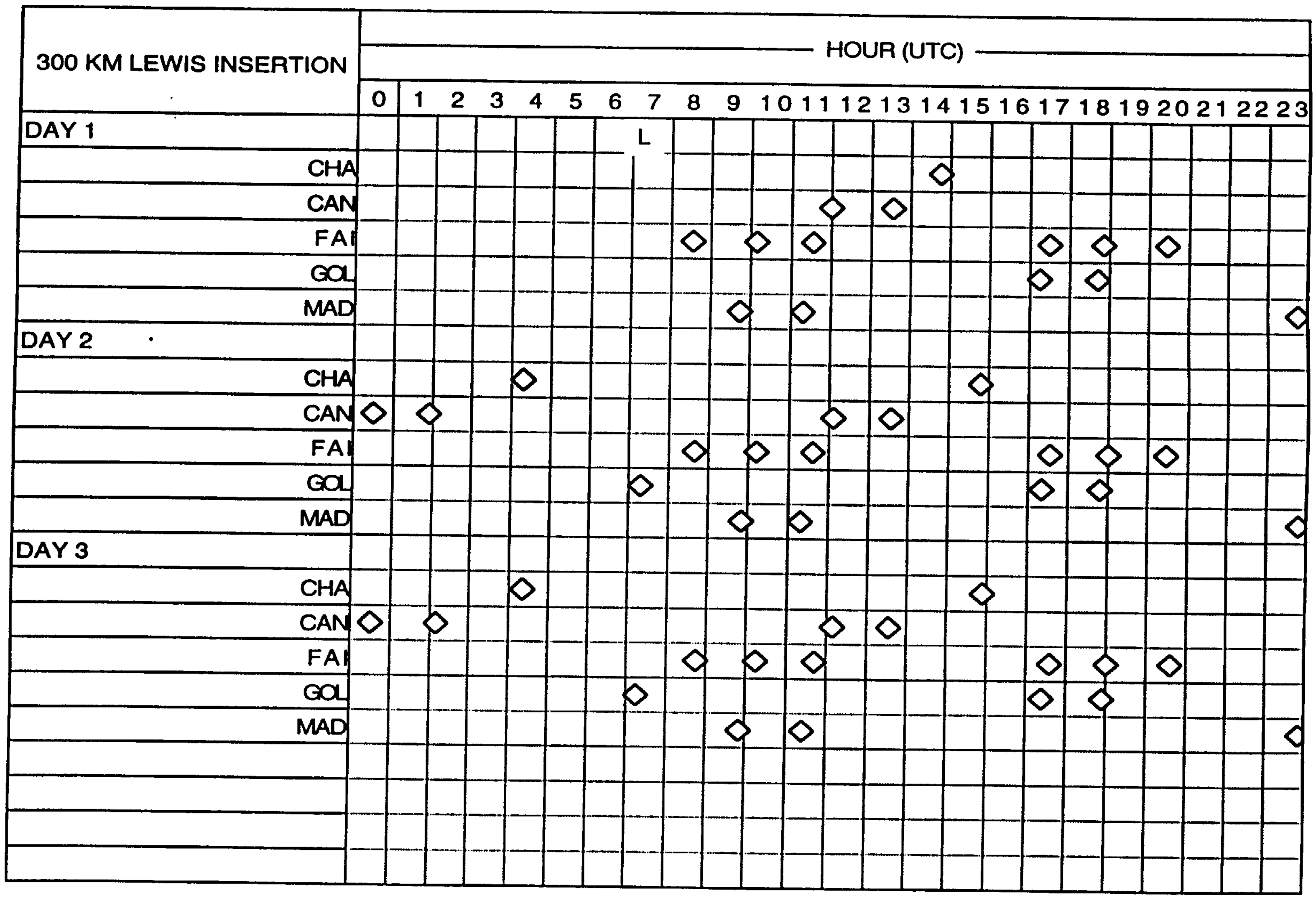
LEO - ASCENT PROFILE

Preliminary SSTI Event Sequence - 300 km Circular Orbit, 97.45° Inclination

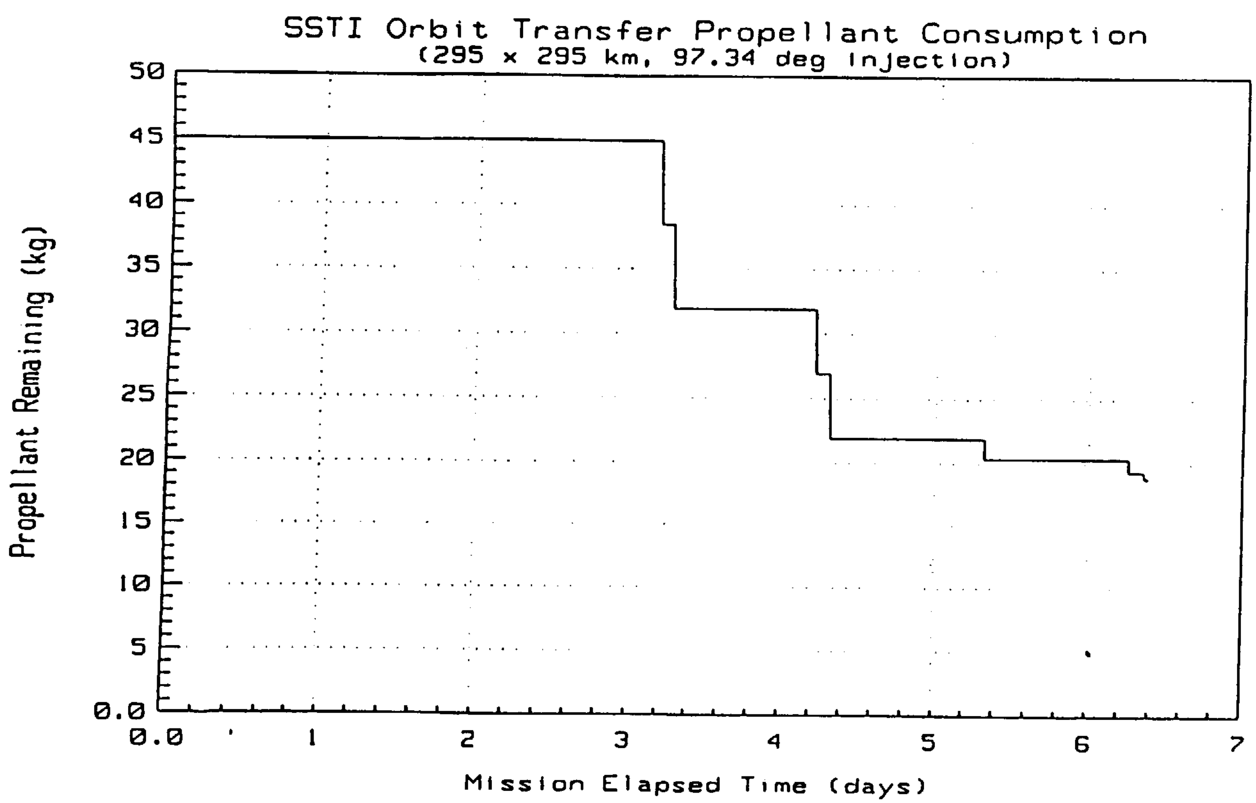
	Time (sec)	Altitude (kft)	Range (nm)	Latitude (deg)	Longitude (deg)
Stage 1 Ignition	0	0.6	0.0	34.58	-120.63
Maximum Dynamic Pressure	35	31.7	4.2	34.51	-120.64
Maximum Axial Acceleration	73	120.4	28.5	34.12	-120.74
Stage 1 Burnout / Begin Ascent Coast Phase	92	188.8	53.6	33.71	-120.84
Nose Fairing Eject	152	363.2	141.5	32.27	-121.20
Stage 1 Separation/ESBM Ignition	157	373.5	149.0	32.15	-121.23
Maximum Acceleration	287	507.7	441.7	27.38	-122.38
ESBM Burnout / Begin Transfer Coast	311	535.7	532.4	25.90	-122.71
ESBM Separation/OAM Ignition	321	548.6	572.0	25.25	-122.86
OAM Burnout / Orbit Injection	1356	984.3	4673.3	-41.72	-137.37

LEO - EARLY MISSION EVENTS

Event	Time
SLAM On	Pre-launch
Launch	T = 0
Fairing Open	T = 152 sec. (altitude = 111 km)
Separation	T = 23 min.
Arrays Deploy	T = 24 min.
Deployment Motion Damped	T = 34 min.
ACS On	T = 34 min.
Exit eclipse	T = 35 min.
Sun Acquisition	T = 37 min.
ISV determination	T = 56 min. (LMSC/IOS?)
First command opportunity	T = 84 min. (Fairbanks)
Second command opportunity	T = 143 min. (Madrid)
HSI Power On	T = 180 min.
Earth Acquisition	T = 190 min. (over pole)


300 KM LEWIS INSERTION
HOUR (UTC)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
L
DAY 1
CHA
CAN
FAI
GOL
MAD
DAY 2
CHA
CAN
FAI
GOL
MAD
DAY 3
CHA
CAN
FAI
GOL
MAD

LEO - ORBIT RAISE MANEUVER



Chantilly + DSN + Alaska -> 18 contacts/day in insertion orbit.

7 burns required (3 Hohmann transfers + 1 inclination change) over 3 day period. This is power conservative approach.

Inclination change burn optimal at nodal crossing time.

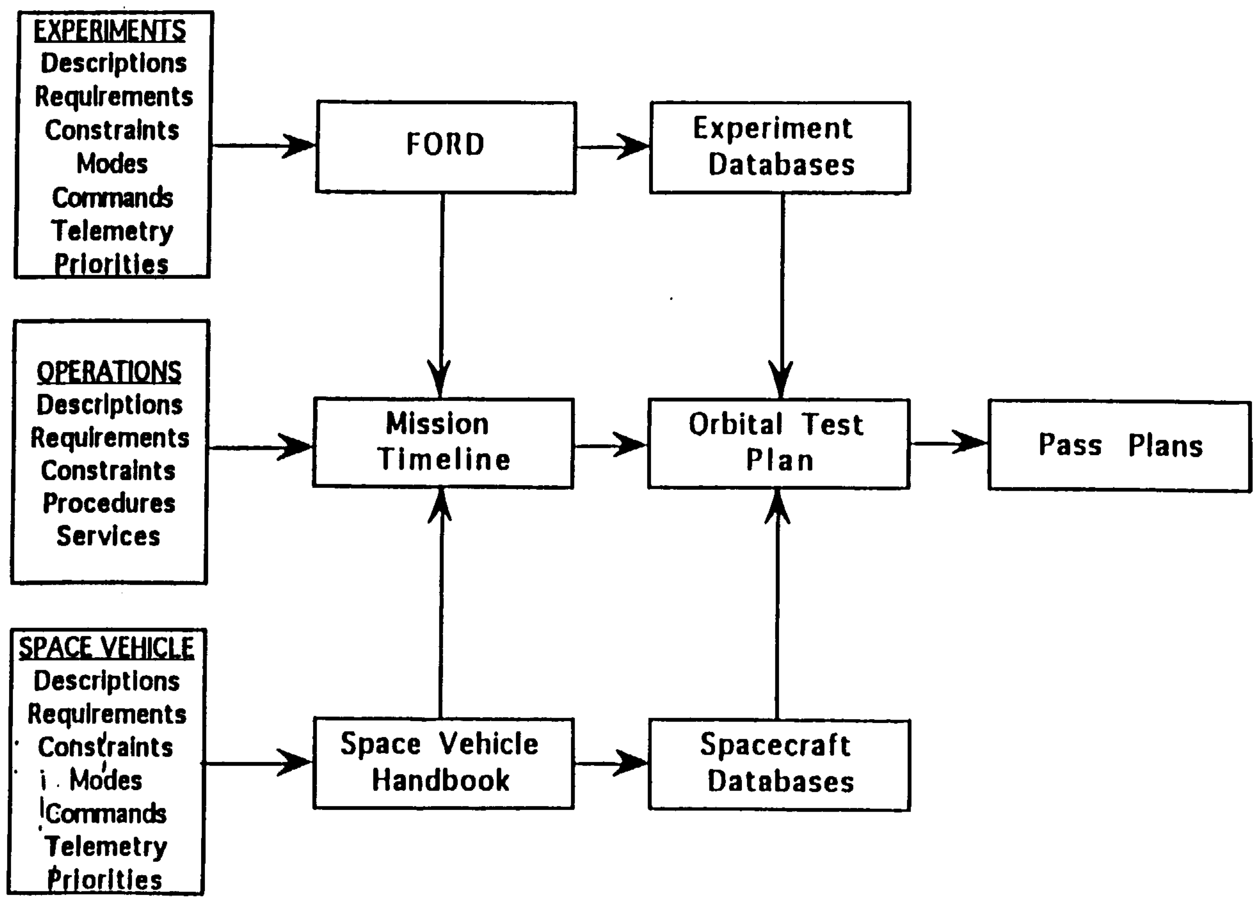
Hohmann transfer burn start times are discretionary.

Burn durations will exceed contact durations - can sync start or stop with contact.

CONTINGENCY OPERATIONS

- **Flight Segment**
  - Flight subsystem built-in safeguards
  - Stored procedures for fallback to redundant equipment
  - Stored procedures for “routine” contingencies
  - Standard practice:
    - » safe the vehicle
    - » employ fallback or routine contingency procedures
    - » develop workaround procedures as required
- **Ground Segment**
  - DSN provides contingency command and telemetry capability
  - Alaska can provide extra contacts based on prioritization among multiple users

PLANNING & DOCUMENTATION FLOW



DOCUMENTATION STATUS

- FORD
  - Telephone TIMs held with experimenters
  - GSFC TIMs attended
  - ICDs
  - ICDA-1 and ICDA-2 material
  - Version 1.2 released for comment 1/10/95 to:
    - » experimenters
    - » system engineering
    - » subsystem engineers
  - Baseline version 2.0 will be released 1/31/95 for signature cycle
- Spacecraft Handbook
  - Begun 1/3/95, document trails CDA
  - Engineering support needed

FORD "RESULTS"

- No show-stoppers
- Design is well-informed by experiment requirements
- Experiment operations concepts well-developed
- Command lists greatly improved from ICDA-1
- ICD process has facilitated Flight Ops requirements
- Subsystem capability statements are current to ICDA-2

OPERATIONS TEST PLANS

- Ground system acceptance test
- Compatibility test with DSN van - 5 days*
- Compatibility test with MGS trailer - 3 days*
- Operations participation in spacecraft and experiment I & T at TRW I & T facility
- LEO spacecraft rehearsal
- LEO experiment rehearsal
- Nominal operations rehearsal

* NASA expressed preference - to be iterated

APPENDIX A

System Specification

Requirements Verification Matrix

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
1	1	INTRODUCTION	Title Only			
2	1.1	Scope	Introduction			
3	2	APPLICABLE DOCUMENTS	Introduction			
4	2.1	Referenced TRW Documents	Listing of Referenced TRW documents in the body of the specification			
5	2.2	Referenced Government Documents	Listing of Referenced Government documents in the body of the specification			
6	2.3	Other Referenced Non Government Documents	Listing of Referenced Non-Government documents in the body of the specification			
7	3	REQUIREMENTS	SSTI Requirements based on Goals and Objectives of NASW-4945	SSTI Lewis Program meets Goals and Objectives of NASW-4945	Requirements Flow Down to major SSTI Specifications	SY1-038, SY26-005, SY27-010
8	3.1	System Definition	Description Only			
9	3.1.1	General Description	Identifies the SSTI Segments: Spacecraft, Ground, Data Management (Stennis), and Launch Vehicle	SSTI LEWIS Program contains all segments described	Inspection and Test	Final Integrated Systems Test
10	3.1.1.1	Spacecraft Segment	Describes the Subsystems, Primary Payloads, Independent Technology Demos and Payload Support Technology Demos that are a part of SSTI	SSTI Spacecraft contains all components specified in the Specification	Inspection and Test	Final Integrated Systems Test

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
11	3.1.1.2	Ground Segment	Describes Ground Segment Subsystems and compatibility with NASA DSN, University of Alaska and Stennis ground stations. Describes operational relationship between Chantilly ground station and Stennis	SSTI Spacecraft and Chantilly ground station compatible with NASA DSN, University of Alaska and Stennis	Analysis and Test	Compatibility Test during final Spacecraft Integration will check system end to end
12	3.1.1.3	Data Management Segment	Describes NASA Stennis Space Center's role in management of SSTI Lewis Data and tasking of Lewis Spacecraft			
13	3.1.1.4	Launch Segment	Describes Launch Segment services			
14	3.1.1.5	Interface Definition	Listing of critical Interface Documents between major SSTI segments and ground stations	Interfaces are compatible	Test, Inspection and Analysis	Launch Vehicle ICD will have its own Verification matrix. Compatibility between Ground Stations and Ground Station to Spacecraft to be verified by Compatibility Test during final spacecraft IST
15	3.1.2	Payloads Definition and User-Based Mission Requirements	Summary of User (HSI/LEISA/UCB) based requirements	Derived requirements are specified in Section 3.2		
16	3.1.2.1	Primary Payload Instruments	Description Only			

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
17	3.1.2.1.1	Hyper-Spectral Imager (HSI)	Collect spectrally resolved sunlit earth radiance image data over multiple bands within the visible, very near infrared (VNIR) and short wave infrared (SWIR) wavebands	Complies	Test	HSI Unit level performance tests and Spacecraft IST HSI Requirements Verification Matrix written against HSI Specification SS31-002
18	3.1.2.1.2	Linear Etalon Imaging Spectral Array (LEISA)	Collect spectrally resolved sunlit earth radiance image data in near infrared to short wave infrared (near IR - SWIR) bands with long, broad swath regions near or far from the SSTI ground track	Complies	Test	LEISA Unit level performance tests
19	3.1.2.1.3	Ultraviolet Cosmic Background Spectrometer (UCB)	Collect spectrally resolved photon count data along sidereal directions continually over multiple orbits during eclipse to construct a sky map-spectrum of the diffuse extreme ultraviolet cosmic background.	Complies	Test	UCB Unit level performance tests
20	3.1.2.2	Payload Support Technology Demonstrations and Equipment	Description Only			
21	3.1.2.2.1	Pulse Tube Cryocoolers	Provide cryogenic cooling for HSI and LEISA sensor units	Complies	Test	HSI and UCB Unit level performance tests
22	3.1.2.2.2	Optical Pointing Assembly (OPA)	Provide LEISA with expanded field of regard without spacecraft attitude variations	Complies	Test	Spacecraft IST

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
23	3.1.2.2.3	Payload Electronics Assembly (PEA)	Support payload instruments by providing the electronics for the cryocoolers, the OPA and the magnetically suspended reaction wheel	Complies	Test	HSI Test bed and Spacecraft IST
24	3.1.2.2.4	Data Compression Electronics and Software for Lossless and Lossy Data Compression	Lossless and lossy data compression techniques shall be demonstrated on-orbit. Compression ratios > 2:1, selectable by ground command, shall be demonstrated	Complies	Test	Spacecraft IST
25	3.1.2.2.5	Fiber Optic Data Bus (FODB)	Demonstrate the capability for transferring data from the HSI to the Data Management Subsystem at rates sufficient to support the maximum output rates of the HSI.	Complies	Test	Spacecraft IST
26	3.1.2.2.6	Solid State Recorder (SSR)	Store > 2 Gbits of data at the end of mission life	Complies, 4 Gbits capacity exists at BOL	Analysis, Test	HSI Test bed and Spacecraft IST
27	3.1.2.2.7	Recorder Interface Module (RIM)	Provide MIL-STD-1553B, wire and FODB interfaces from spacecraft payloads to the Solid State Recorder	Complies	Test	Spacecraft IST
28	3.1.2.3	Independent Technology Demonstrations	Description Only			

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
29	3.1.2.3.1	Global Positioning System (GPS) Attitude Determination	Provide the ability to determine spacecraft attitude knowledge to within 0.15 degrees (1 sigma value) by processing GPS obtained data. GPS time, position and velocity shall also be used to support payload data collection	Complies	Test	Spacecraft IST
30	3.1.2.3.2	Magnetically Suspended Reaction Wheel	Demonstrate the capability of the device to generate attitude corrections to a spacecraft by measuring the on-orbit torques generated by the reaction wheel	Complies	Test	Spacecraft IST
31	3.1.2.3.3	Microcosm Orbit Control Kit	Demonstrate autonomous orbit altitude maintenance by providing periodic maneuver (delta V) advisory commands for ground evaluation.	Complies	Test	Spacecraft IST
32	3.1.2.3.4	Cascade Solar Cell Experiment	Measure output performance of cascade cells with standard and infrared reflecting coverglass on-orbit	Complies	Test	Spacecraft IST
33	3.1.2.3.5	Amorphous Silicon Solar Cell Experiment	Measure output performance of amorphous silicon thin film solar cells on-orbit	Complies	Test	Spacecraft IST
34	3.1.2.3.6	Gallium Arsenide Solar Cell Experiment	measure output performance of Gallium Arsenide solar cells on-orbit	Complies	Test	Spacecraft IST
35	3.1.2.3.7	Metal Matrix Composite Thermal Strap	Demonstrate the capability to transfer heat from the generating source to the spacecraft radiator	Complies	Test	Spacecraft Thermal Vacuum Test

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
36	3.1.2.3.8	Spacecraft Loads and Acoustics Measurement (SLAM)	Measure acceleration and acoustic loads during launch and on-orbit operations	Complies	Test	Spacecraft IST and Vibration Test
37	3.1.2.3.9	Micro-machined Accelerometers	Measure acceleration and acoustic loads during launch and on-orbit operations	Complies	Test	Spacecraft IST and Vibration Test
38	3.1.2.3.10	Radiation Environment Measurement Experiment	Measure the linear energy transfer (LET) spectrum as a function of orbital position (latitude, longitude and time) in order to validate radiation transport codes and to improve LEO radiation environment models	Complies	Test	Spacecraft IST
39	3.1.2.3.11	Enhanced Attitude Control System Experiment	Evaluate the feasibility of implementing a high bandwidth, high performance Attitude Control System for the SSTI Spacecraft in the Normal Mode	Complies	Test	Spacecraft IST
40	3.1.2.3.12	Cloud and Feature Editing Experiment	Demonstrate the ability to identify clouds and terrestrial features (such as snow cover) at pixel level in post-flight processing of HSI and/or LEISA data	Complies	Not Applicable	This is a post processing experiment
41	3.1.2.3.13	Wide Field of View Star Tracker (WSTA)	Demonstrate the potential for supporting a high-accuracy, lightweight gyroless attitude control system	Complies	Test	Spacecraft IST
42	3.1.3	System Operational Requirements	Description Only			

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
43	3.1.3.1	Launch and Checkout Phase	Description Only			
	3.1.3.1a		Launch on LLV controlled by Vandenberg AFB	Complies	Test	Launch @ Vandenberg
	3.1.3.1b		Selected Spacecraft SOH Telemetry available at LMSC Checkout van	Complies, selected telemetry passed through L/V interface via fiber optic lines to TRW terminal in LMSC checkout van	Test	Spacecraft IST and checkout of facilities at Vandenberg
	3.1.3.1c		Collection and storage of SLAM data during launch events	Complies, discrete sent to Spacecraft from Launch Vehicle to start SLAM data collection process	Test	Spacecraft IST
	3.1.3.1d		Launch Vehicle inserts Spacecraft into parking orbit	Complies, LLV to insert Spacecraft into a 295 km circular x 97.35° (worst case) orbit	Analysis	Responsibility of LMSC
	3.1.3.1e		Launch Vehicle separates itself from spacecraft	Complies	Test	Responsibility of LMSC
	3.1.3.1f		Launch Vehicle performs Collision/Contamination Avoidance Maneuver (C/CAM)	Complies	Analysis	Responsibility of LMSC
	3.1.3.1g		Spacecraft autonomously initializes itself upon separation from Launch Vehicle, deploys arrays and maneuvers to a pre-determined attitude state.	Complies	Test	Spacecraft IST

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
	3.1.3.1h		Spacecraft shall safe critical systems and minimize on-board power consumption in the event of a detected anomaly	Complies	Test	Spacecraft IST
	3.1.3.1i		Early orbit Spacecraft contacts shall be through NASA DSN and Chantilly Ground Stations	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
	3.1.3.1j		3 days allocated to time in the Parking Orbit	Complies	Analysis	D22882 Orbital Test Plan
	3.1.3.1k		Orbit Adjust Burns performed by the Spacecraft required to raise spacecraft orbit from parking to operational orbit	Complies	Analysis Test	IOC Number SSTI.94.SEI.077 Propellant Budget Calculations & Propulsion subsystem Test
	3.1.3.1l		5 days allocated to orbit transfer time	Complies	Analysis	D22882 Orbital Test Plan
	3.1.3.1m		30 days allocated to spacecraft checkout time once in operational orbit	Complies	Analysis	D22882 Orbital Test Plan
44	3.1.3.2	Normal Operations Phase	Description Only			
	3.1.3.2a		SSTI Mission support requires incremental planning requests from Stennis	Complies	Test	End to End Compatibility Test
	3.1.3.2b		Stennis tasking requests required to Chantilly 2 weeks before expected execution	Complies	Test	End to End Compatibility Test

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
	3.1.3.2c		Downlinked data received at Stennis or University of Alaska must be sent to Chantilly for pre-processing prior to final transmittal to Stennis	Complies	Test	End to End Compatibility Test
	3.1.3.2d		Stennis performs radiometric and geometric corrections to SSTI data	Complies	Test	End to End Compatibility Test
	3.1.3.2e		Final SSTI data stored at Stennis with direct access via Internet			Stennis responsibility
45	3.1.3.3	Spacecraft Conditions, States and Modes	Description Only			
	3.1.3.3		Spacecraft to provide the following states			
	3.1.3.3a		Test State	Complies	Test	Spacecraft IST
	3.1.3.3b		Launch State	Complies	Test	Spacecraft IST
	3.1.3.3c		Initiation State	Complies	Test	Spacecraft IST
	3.1.3.3d		Maneuver State	Complies	Test	Spacecraft IST
	3.1.3.3e		Normal State	Complies	Test	Spacecraft IST
	3.1.3.3f		Safe Haven State	Complies	Test	Spacecraft IST
46	3.1.4	Listing of Government Furnished Property and Facilities	Description Only			
47	3.1.4.1	Government Furnished Property				
	3.1.4.1a		One Cryocooler	Complies	Test	HSI and LEISA Subsystem Tests
	3.1.4.1b		One Optical Pointing Assembly	Complies	Test	Spacecraft Thermal Vacuum Test

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
	3.1.4.1c		One Magnetically Suspended Reaction Wheel	Complies	Test	Spacecraft IST
48	3.1.4.2	Government Furnished Facilities				
	3.1.4.2a		Vandenberg Launch Facility and Range Services	Complies	Test	Launch Rehearsals
	3.1.4.2b		NASA Ground Stations via NASCOM Line 5 for spacecraft contact	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
	3.1.4.2c		Stennis Space Center to task SSTI Lewis and receive final data	Complies		Stennis responsibility
	3.1.4.2d		Stennis Space Center to perform final data processing, archiving and distribution	Complies		Stennis responsibility
49	3.2	Characteristics	Description Only			
50	3.2.1	Performance Characteristics	Title Only			
51	3.2.1.1	Orbital Conditions	Title Only			
52	3.2.1.1.1	Parking Orbit	Worst case parking orbit: 295 x 295 km, 97.45 +/- 0.06 degrees inclination. 10:50 am +/- 20 minutes ascending node	Complies with one exception. Launch vehicle capability for inclination is 97.45 +/- 0.1 degrees. All SSTI propellant budget calculations use the +/- 0.1 Launch Vehicle capability value. System Spec to be revised.	Analysis, Simulations	Requirement flowed into Launch Vehicle ICD which will have its own Verification matrix

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
53	3.2.1.1.2	Operational Orbit	Operational Orbit: 523+/-10 km with 10:50 am +/- 20 minutes ascending node. 7 day ground track revisit, continuous orbit swath coverage based on spacecraft +/- 22 degree roll view angle.	Complies	Analysis, Simulations	Complete orbital perturbation simulations not yet completed. Propellant budgets calculated in SSTI.94.SEI.077
54	3.2.1.2	Orbit Determination and Control	Title Only			
55	3.2.1.2.1	Operational Orbit Stationkeeping	Ground Segment to have capability to support stationkeeping requirements of the operational orbit	Complies	Analysis	Similarity to other systems
56	3.2.1.2.2	Ground-Based Spacecraft Tracking	Spacecraft to be compatible with NASA DSN tracking methods	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
57	3.2.1.2.3	On-Board Position and Velocity Knowledge	Spacecraft capable of determining absolute position and velocity knowledge	Complies	Test	Final Integrated Systems Test
58	3.2.1.3	Communications Characteristics	Spacecraft and Ground Station to provide one uplink and two downlink communications modes	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
59	3.2.1.3.1	Space-to-Ground Contact				
	3.2.1.3.1a		Spacecraft and Ground Communications systems shall be designed for one contact per orbit	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
	3.2.1.3.1b		Spacecraft able to function autonomously without ground contact for a period of 3 days	Capability to be verified	Analysis	

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
	3.2.1.3.1c		SSTI System to accomplish its mission with daily ground link time of 20 minutes	Complies	Analysis and Simulation	ICDA-2 Mission Operations Briefing
	3.2.1.3.1d		Ground Segment able to transmit and receive to spacecraft while in parking, transfer or operational orbits	Complies	Analysis	Link Budget Analysis
60	3.2.1.3.2	Command Generation and Receiving	Chantilly Ground Station uplink antenna to generate sufficient EIRP to transmit command data to the spacecraft	Complies	Test	Harris CDRS System Acceptance Test
61	3.2.1.3.2.1	Command Frequency	Command Frequency at 2095.172 MHz	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
62	3.2.1.3.2.2	Command Data Rates	Uplink Command data rate at 2.000 Kbits/sec	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
63	3.2.1.3.2.3	Command Receiver Performance	Spacecraft capable of receiving commands at any orientation including tumbling at 2.5 degrees/sec	Complies	Analysis and Test	Antenna Pattern Test and Link Budget Analysis
64	3.2.1.3.2.4	Command Bit Error Rate	Command BER less than $1x10^{-6}$ more than 95% or the time	Complies	Analysis and Demonstration	Link Budget Analysis and Spacecraft Functional Test
65	3.2.1.3.2.5	Uplink Activation	Spacecraft receiver activated by presence of uplink signal	Complies, receiver is on all the time	Test	Spacecraft Functional Test
66	3.2.1.3.3	Mission Data and Telemetry Transmission	Spacecraft downlink antenna to generate sufficient EIRP to transmit data to the ground station	Complies	Analysis and Test	Antenna Pattern Test and Link Budget Analysis

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
67	3.2.1.3.3.1	Telemetry Frequency	Telemetry frequency at 2275.300 MHz	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
68	3.2.1.3.3.2	Telemetry Data Rate	Mode 1 downlink data rate at 8.000 Kbits/sec and Mode 2 downlink data rate at 2.048 Mbits/sec	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
69	3.2.1.3.3.3	Telemetry Data Bit Error Rate	Telemetry BER less than $1x10^{-6}$ more than 95% or the time	Complies	Analysis and Demonstration	Link Budget Analysis and Spacecraft Functional Test
70	3.2.1.3.3.4	Payload and Technology Demonstration Data Bit Error Rate	Telemetry BER less than $1x10^{-9}$ more than 95% or the time	Complies	Analysis and Demonstration	Link Budget Analysis and Spacecraft Functional Test
71	3.2.1.3.3.5	Downlink Activation				
	3.2.1.3.3.5 a		Mode 1 and 2 not transmitted simultaneously	Complies	Test	Spacecraft Functional Test, Spacecraft to Chantilly and NASA DSN Compatibility Test
	3.2.1.3.3.5 b		Mode 1 and 1 capable of being interleaved	Complies	Test	Spacecraft Functional Test, Spacecraft to Chantilly and NASA DSN Compatibility Test
	3.2.1.3.3.5 c		Mode 1 and 2 selectable by ground command	Complies	Test	Spacecraft Functional Test, Spacecraft to Chantilly and NASA DSN Compatibility Test
72	3.2.1.3.3.6	Downlink Performance as a Function of Spacecraft Attitude	Communications performance must be satisfied at off Nadir positions of Pitch +/- 22°, Roll +/- 22°, Yaw any angle	Complies	Analysis and Test	Antenna Pattern Test and Link Budget Analysis

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
73	3.2.1.3.4	Link Parameters	Title Only			
74	3.2.1.3.4.1	Loss Allowance	Less than 1.0 dB Polarization losses and 3.0dB passive ground losses to be accommodated	Complies	Analysis	Included in Link Budget Calculations
75	3.2.1.3.4.2	Link Margin	Total up and down link margins greater than +3dB. Minimum ground station elevation angle is 5°	Complies, currently +7dB margin (4dB over required minimum)	Analysis and Test	Antenna Pattern Test and Link Budget Analysis
76	3.2.1.4	Spacecraft On-Board Command Processing Requirements	Title Only			
77	3.2.1.4.1	Command Execution	Stored Commands loaded into memory, time-tagged for execution in synchronization with spacecraft clock referenced to on-board time	Complies	Test	Spacecraft Functional Test
78	3.2.1.4.2	Commands Verification	Commands verified by spacecraft software. Accepted/Rejected command counter data telemetered to ground	Complies	Test	Spacecraft Functional Test
79	3.2.1.4.3	Types of Stored Commands	Provision made for absolute and relative timed commands	Complies	Test	Spacecraft Functional Test
80	3.2.1.4.4	Onboard Command Memory	DMS to provide command memory for 72 hours of autonomous operations	Complies	Test	Spacecraft Functional Test

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
81	3.2.1.4.5	Onboard Memory Loads	Provision made for up or down loading of RAM or ROM memory. Sufficient buffer to compare ground loads can be compared to their load images before transfer to active memory	Complies	Test	Spacecraft Functional Test
82	3.2.1.4.6	Uplinking of Stored Commands	Spacecraft shall accept commands at any time	Complies	Test	Spacecraft Functional Test
83	3.2.1.4.7	Command Deletion or Overwrite	Capability to overwrite or delete stored command	Complies	Test	Spacecraft Functional Test
84	3.2.1.4.8	Synchronous Command Execution	Commands from all sources to execute without interference from each other	Complies	Test	Spacecraft Functional Test
85	3.2.2	Physical Characteristics	Title Only			
86	3.2.2.1	Spacecraft Weight	Maximum spacecraft weight 850 lb.. LMSC separation ring 11.3 lb. max. Maximum spacecraft separated weight 861.3 lb.	Complies	Test	Weight and Mass properties measurements
87	3.2.2.2	Spacecraft Mass Properties	Spacecraft center of mass compatible with LLV	Complies	Analysis Test	SR4-047 Weight and Mass properties measurements
88	3.2.2.3	Spacecraft Dimensional Limitations	Spacecraft stowed configuration compatible with LLV static and dynamic envelopes	Complies	Analysis	Coupled Loads Analysis
89	3.2.2.4	Transportation and Storage	Spacecraft and ground segment equipment shall allow for road or air transportation. Shipping container to provide protection from contamination and record maximum environments	Complies	Analysis	Various design documentation

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
90	3.2.3	Security Requirements	Ground segment shall implement measures against electronic and physical breaches of security	Complies	By Design	
91	3.2.4	Reliability and Mission Life	Spacecraft Bus 0.9 @ 3 years Spacecraft Bus 0.8 @ 5 years Spacecraft + HSI 0.7 @ 5 years	Complies	Analysis	D22890 Reliability Allocations Document
92	3.2.5	Maintainability	Spacecraft shall accommodate ground maintenance or repairs	Complies	N/A	By Design
93	3.2.6	Availability	Ground Segment availability 0.95 during spacecraft flight operations	Complies	N/A	By Design
94	3.2.7	Environmental Conditions	Spacecraft to withstand all environments encountered from initial fabrication to on-orbit operations	Complies	Test	Environmental tests conducted per EV2-099, EV1-034 and SR1-0125
95	3.3	Design and Construction	Title Only			
96	3.3.1	Contamination Control	Integration and test procedures to be in accordance with D22893 Contamination Control Plan	Complies	Test	Various Procedures
97	3.3.2	Parts, Materials and Processes	Parts to meet design life and reliability requirements in D22876 Mission Assurance Plan	Complies	Inspection	Parts lists approved by Mission Assurance
98	3.3.3	Identification, Nameplates and Marking	Description of Identification Tag contents	Complies	Inspection	Various final inspections
99	3.3.4	Software	Description Only			
100	3.3.5	Interchangeability	Components with the same part number shall be interchangeable in form, fit, function, reliability and qualification status	Complies	TRW Q/A procedures	Various final inspections

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
101	3.3.6	Safety	Comply with WRR 127-2 safety requirements	Complies	Analysis and procedures	D22886 Accident Risk Assessment report. Launch Site procedures
102	3.4	Documentation	Description Only			
103	3.5	Personnel and Training	TRW to provide program and materials to train personnel to operate the SSTI system	Complies	Documentation and Procedures	D22872 Operator Positional handbook, D22874 Spacecraft handbook, D22882 Orbital Test Plan, Rehearsals
104	4	QUALITY ASSURANCE PROVISIONS	Quality methods and testing to be performed din accordance with D22876 Mission Assurance Plan	Complies	Procedures and inspections	Various test procedures and inspections
105	4.1	General Requirements				
	4.1a		Spacecraft level acceptance test in accordance with EV1-034 and SR1-0125	Complies	Test	Spacecraft Vibration, Thermal and EMC Test
	4.1b		Component level acceptance testing in accordance with EV2-099	Complies	Test	Component Vibration, Thermal, and EMC Tests
	4.1c		Ground segment testing in accordance with D22880	Complies	Test	Various tests
106	4.1.1	Responsibility for Tests	Definition Only			
107	4.2	Quality Conformance Tests and Inspections				
	4.2a		Spacecraft to be subjected to s series of Performance verification tests in SR4-044	Complies	Test	Various tests

SSTI SY1-038 System Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
	4.2b		Ground segment to be subjected to a series of performance verification tests in D22880	Complies	Test	Various tests
	4.2c		Spacecraft to ground station compatibility test to be performed	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
	4.2d		SSTI to NASA Ground Network compatibility test to be performed according to STDN No. 408.1	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
107	5	PREPARATION FOR DELIVERY	All elements of the spacecraft or its components shall be protected from degradation from environments during shipping , handling or storage	Complies	Inspection	Inspection of configuration to be shipped
108	6	REQUIREMENTS MATRIX	A requirements Matrix shall be prepared for the following items			
	6a		SSTI ground, launch and spacecraft segments			
	6b		Subsystems of SSTI segments (i.e. TT&C, EPDS, Thermal, DMS subsystems)			
	6c		Payload Instruments			
	6d		Payload Support Technology Demonstrations			
	6e		Independent Technology Demonstrations			

APPENDIX B
Spacecraft Specification
Requirements Verification Matrix

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
1	1	INTRODUCTION	Title Only			
2	1.1	Scope	Introduction			
3	1.2	Spacecraft Description	Introduction			
4	2	APPLICABLE DOCUMENTS	Title Only			
5	2.1	Referenced TRW Documents	Listing of Referenced TRW documents in the body of the specification			
6	2.2	Referenced Government Documents	Listing of Referenced Government documents in the body of the specification			
7	2.3	Other Referenced Non Government Documents	Listing of Referenced Non-Government documents in the body of the specification			
8	3	REQUIREMENTS	SSTI Requirements based on Goals and Objectives of NASW-4945	SSTI Lewis Program meets Goals and Objectives of NASW-4945	Requirements Flow Down to major SSTI Specifications	SY1-038, SY26-005, SY27-010
9	3.1	Spacecraft-Level Requirements	Description Only			
10	3.1.1	Spacecraft Definition	Identifies major subsystems that make up the SSTI Lewis Spacecraft	SSTI LEWIS Spacecraft contains all subsystems described	Inspection and Test	Final Integrated Systems Test
11	3.1.1.1	Item Description	Describes the Subsystems, Primary Payloads, Independent Technology Demos and Payload Support Technology Demos that are a part of SSTI	SSTI Spacecraft contains all components specified in the Specification	Inspection and Test	Final Integrated Systems Test
12	3.1.1.2	Spacecraft Interfaces	Title Only			

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
13	3.1.1.2.1	Spacecraft-to-Lockheed Launch Vehicle (LLV) Interface	Spacecraft to meet interface requirements per LMSC ICD No. 1A50101	Complies	Inspection, Analysis and Test	Verification Matrix for Launch Vehicle ICD to be generated by Launch Vehicle Manager
14	3.1.1.2.1.1	Spacecraft Envelope	Spacecraft stowed configuration compatible with LLV static and dynamic envelopes	Complies	Analysis	Coupled Loads Analysis
15	3.1.1.2.1.2	Payload Attachment Interface	Payload Attachment interface requirements located in LMSC ICD No. 1A50101	Complies	Inspection and Test	Fit up of Launch Vehicle separation system
16	3.1.1.2.1.3	Launch and Separation Loads and Environments	Spacecraft to accommodate environments as specified in EV1-034 and EV2-099	Complies	Test	Component and Spacecraft level Environmental Tests
17	3.1.1.2.1.4	Spacecraft-to-LLV Operational Interface	Spacecraft electrical interface to comply with interface requirements as specified in LMSC ICD No. 1A50101	Complies	Test	Spacecraft IST and fit up of Launch vehicle Separation System (with electrical interface)
18	3.1.1.2.1.5	Spacecraft-to-LLV Coordinate System	Spacecraft of LLV coordinate system shall be as depicted in Figure 3-4 of SY26-005	Complies	Inspection	By design and inspection at Launch Site when Spacecraft is mated to the Launch Vehicle
19	3.1.1.2.2	Spacecraft-to-Ground Segment Interface	Spacecraft to be capable of communicating with Chantilly, University of Alaska, Stennis and NASA Ground Space Tracking and Data network	Complies	Test	Compatibility tests scheduled between the spacecraft and Chantilly and NASA Ground Stations
20	3.1.1.2.3	Spacecraft Bus-to-Payload Instrument and Spacecraft Component Interfaces	Description Only			

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
21	3.1.1.2.3.1	Payload and Component Alignments and Pointing Accuracy	Component Alignments specified in SR4-049. Pointing accuracy budgets allocated per D22891	Complies	Inspection & Test	Component, and subassembly inspections. Alignments during Integration and Test
22	3.1.1.2.3.2	Payload and Critical Component Fields-of View	Required component fields of view implemented by placing components on spacecraft structure. Spacecraft layouts depicted in L305581	Complies	Inspection & Test	Component, and subassembly inspections. Alignments during Integration and Test
23	3.1.1.2.3.3	Payload and Component Weight and Center-of-Mass (CM)	Not to exceed weights for all spacecraft components is given in SR4-047	Complies	Inspection	Component, and subassembly inspections
24	3.1.1.2.3.4	Payload and Component Access	Spacecraft shall accommodate ground maintenance or repairs. Access required to spacecraft activation connectors through the payload fairing door	Complies	N/A	By Design
25	3.1.1.2.3.5	Payload and Component Power	Spacecraft Bus provides 24.0 to 38.6 volts. During low voltage shut down (23.0 volts) critical component listed must be able to function in a degraded mode	Complies	Test	Low voltage recovery test
26	3.1.1.2.3.6	Payload and Component Thermal	Component temperatures to be maintained within appropriate operating or survival temperatures	Complies	Test	Thermal Balance Test during Thermal Vacuum

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
27	3.1.1.2.3.7	Payload and Component Command and Telemetry	Spacecraft to provide payload and component telemetry and command signals per ICDs and Subsystem requirements. Telemetry Allocations specified in D22883. Command Allocations specified in D22884	Complies	Test	Final Integrated Systems Test
28	3.1.1.2.4	Spacecraft GSE-to-Ground Segment Interfaces	Spacecraft and EGSE shall interface with the GSFC Communication test Van for Rf compatibility testing	Complies	Test	NASA DSN Compatibility Test
29	3.1.1.3	Spacecraft Conditions, States and Modes Description	Description Only			
30	3.1.1.3.1	Test, Launch, and On-Orbit Conditions	Launch on LLV controlled by Vandenberg AFB	Complies	Test	Launch @ Vandenberg
	3.1.1.3.1a		Selected Spacecraft SOH Telemetry available at LMSC Checkout van	Complies, selected telemetry passed through L/V interface via fiber optic lines to TRW terminal in LMSC checkout van	Test	Spacecraft IST and checkout of facilities at Vandenberg
	3.1.1.3.1b		Collection and storage of SLAM data during launch events	Complies, discrete sent to Spacecraft from Launch Vehicle to start SLAM data collection process	Test	Spacecraft IST
	3.1.1.3.1c		Launch Vehicle inserts Spacecraft into parking orbit	Complies, LLV to insert Spacecraft into a 295 km circular x 97.35o (worst case) orbit	Analysis	Responsibility of LMSC

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
	3.1.1.3.1d		Launch Vehicle separates itself from spacecraft	Complies	Test	Responsibility of LMSC
	3.1.1.3.1e		Launch Vehicle performs Collision/Contamination Avoidance Maneuver (C/CAM)	Complies	Analysis	Responsibility of LMSC
	3.1.1.3.1f		Spacecraft autonomously initializes itself upon separation from Launch Vehicle, deploys arrays and maneuvers to a pre-determined attitude state.	Complies	Test	Spacecraft IST
	3.1.1.3.1g		Spacecraft shall safe critical systems and minimize on-board power consumption in the event of a detected anomaly	Complies	Test	Spacecraft IST
	3.1.1.3.1h		Early orbit Spacecraft contacts shall be through NASA DSN and Chantilly Ground Stations	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
	3.1.1.3.1i		3 days allocated to time in the Parking Orbit	Complies	Analysis	D22882 Orbital Test Plan
	3.1.1.3.1j		Orbit Adjust Burns performed by the Spacecraft required to raise spacecraft orbit from parking to operational orbit	Complies	Analysis Test	IOC Number SSTI.94.SEI.077 Propellant Budget Calculations & Propulsion subsystem Test
	3.1.1.3.1k		5 days allocated to orbit transfer time	Complies	Analysis	D22882 Orbital Test Plan
	3.1.1.3.1l		30 days allocated to spacecraft checkout time once in operational orbit	Complies	Analysis	D22882 Orbital Test Plan
31	3.1.1.3.2	Test, Launch, and On-Orbit States	Description Only			

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
	3.1.1.3.2a		Spacecraft to provide the following states			
	3.1.1.3.2b		Test State	Complies	Test	Spacecraft IST
	3.1.1.3.2c		Launch State	Complies	Test	Spacecraft IST
	3.1.1.3.2d		Initiation State	Complies	Test	Spacecraft IST
	3.1.1.3.2e		Maneuver State	Complies	Test	Spacecraft IST
	3.1.1.3.2f		Normal State	Complies	Test	Spacecraft IST
	3.1.1.3.2g		Safe Haven State	Complies	Test	Spacecraft IST
32	3.1.1.3.3	Test, Launch and On Orbit Modes	Description Only			
33	3.1.1.3.4	Onboard State/Mode Initialization	The spacecraft shall initialize to the appropriate state/mode upon initial power up of the spacecraft	Complies	Test	Spacecraft IST
34	3.1.1.3.5	Spacecraft State/Mode Transition	The spacecraft shall be capable of transitioning between states and mode by ground command or autonomously	Complies	Test	Spacecraft IST
35	3.1.2	Performance Requirements	Title Only			
36	3.1.2.1	Launch and Deployment Requirements	Title Only			
37	3.1.2.1.1	Launch Vehicle Environment and Compatibility	Spacecraft and components to be designed for compatibility with LLV1 or LLV 2 environments	Complies	Test	Component and Spacecraft Environmental Tests
38	3.1.2.1.2	Spacecraft Operation During Launch	Spacecraft shall monitor and record SLAM data during launch events	Complies	Test	Spacecraft level vibration test

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
39	3.1.2.1.3	Spacecraft Initiation Upon Separation	Spacecraft shall autonomously stabilize itself for tip-off rates up to 2.0 degrees per second. Deploy arrays and begin internal monitoring of functions	Complies Spacecraft can handle up to 5 degrees per second	Test and Analysis	Spacecraft IST
40	3.1.2.1.4	Early-Orbit Ground Contacts	Spacecraft shall be capable of communications with the Chantilly Ground Station and the NASA DSN	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
41	3.1.2.2	Orbital Conditions	Title Only			
42	3.1.2.2.1	Parking Orbit Definition	Worst case parking orbit: 295 x 295 km, 97.45 +/- 0.06 degrees inclination. 10:50 am +/- 20 minutes ascending node	Complies with one exception. Launch vehicle capability for inclination is 97.45 +/- 0.1 degrees. All SSTI propellant budget calculations use the +/- 0.1 Launch Vehicle capability value. System Spec to be revised.	Analysis, Simulations	Requirement flowed into Launch Vehicle ICD which will have its own Verification matrix
43	3.1.2.2.2	Operational Orbit Definition	Operational Orbit: 523+/-10 km with 10:50 am +/- 20 minutes ascending node. 7 day ground track revisit, continuous orbit swath coverage based on spacecraft +/- 22 degree roll view angle.	Complies	Analysis, Simulations	Complete orbital perturbation simulations not yet completed. Propellant budgets calculated in SSTI.94.SEI.077
44	3.1.2.3	Orbit Determination and Control	Title Only			

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
45	3.1.2.3.1	Orbit Transfer	Orbit Adjust Burns performed by the Spacecraft required to raise spacecraft orbit from parking to operational orbit	Complies	Analysis Test	IOC Number SSTI.94.SEI.077 Propellant Budget Calculations & Propulsion subsystem Test
46	3.1.2.3.2	Spacecraft Position Control (Station Keeping)	Spacecraft shall support stationkeeping requirements to maintain operational orbit within specified tolerances	Complies	Analysis Test	IOC Number SSTI.94.SEI.077 Propellant Budget Calculations & Propulsion subsystem Test
47	3.1.2.3.3	Spacecraft Position Knowledge	Spacecraft shall be capable of determining absolute position to less than 150 meters (3 sigma)	Complies	Analysis	Not Yet Performed
48	3.1.2.3.4	Spacecraft Velocity Knowledge	Spacecraft shall be capable of determining absolute velocity to less than 0.6 meters per second (3 sigma)	Complies	Analysis	Not Yet Performed
49	3.1.2.4	Attitude Determination and Control	Title Only			
50	3.1.2.4.1	Autonomous Safing	Spacecraft shall autonomously safe itself upon detection of an anomaly	Complies	Test	Low Voltage recovery test. ACS subsystem test
51	3.1.2.4.2	Spacecraft Attitudes for Payload Support	Spacecraft capable of achieving specified attitudes to support payload data acquisition	Complies	Simulation	ACS software simulations
52	3.1.2.4.3	Payload Boresight Knowledge	Spacecraft shall be capable of determining primary payload sensor boresight to accuracies specified in D22891	Complies	Test and Simulations	Component alignments and ACS software simulations

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
53	3.1.2.4.4	Payload Boresight Control	Spacecraft shall be capable of controlling attitude within 0.04 degrees (3 sigma) in roll and pitch axis and 0.5 degrees (3 sigma) yaw axis	Complies	Simulation	ACS software simulations
54	3.1.2.5	Communications Characteristics	Spacecraft and Ground Station to provide one uplink and two downlink communications modes	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
55	3.1.2.5.1	Uplink and Downlink Modes Definition	Title Only			
56	3.1.2.5.2	Ground Contacts	Title Only			
57	3.1.2.5.2.1	Normal-State Contacts	Normal Operation Spacecraft contacts shall be through Chantilly, University of Alaska, and Stennis Ground Stations	Complies	Test	Spacecraft to Chantilly Compatibility Test
58	3.1.2.5.2.2	Contingency Contacts	Early orbit Spacecraft contacts shall be through NASA DSN and Chantilly Ground Stations	Complies	Test	Spacecraft and Chantilly to NASA DSN Compatibility Test
59	3.1.2.5.2.3	Contact Frequency	Spacecraft and Ground Communications systems shall be designed for one contact per orbit	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
60	3.1.2.5.2.4	Contact Durations	SSTI System to accomplish its mission with daily ground link time of 20 minutes	Complies	Analysis and Simulation	ICDA-2 Mission Operations Briefing
61	3.1.2.5.2.5	Maximum Interval Between Contacts	Spacecraft able to function autonomously without ground contact for a period of 3 days	Complies		

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
62	3.1.2.5.2.6	Ground-Based Tracking Support	Spacecraft shall provide a stable transmit frequency to support Doppler measurements from ground stations	Complies		
63	3.1.2.5.3	Uplink Communications	Title Only			
64	3.1.2.5.3.1	Uplink Frequency	Command Frequency at 2095.172 MHz	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
65	3.1.2.5.3.2	Uplink Data Rate	Uplink Command data rate at 2.000 Kbits/sec	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
66	3.1.2.5.3.3	Uplink Bit Error Rate	Command BER less than 1x10-6 more than 95% or the time	Complies	Analysis and Demonstration	Link Budget Analysis and Spacecraft Functional Test
67	3.1.2.5.3.4	Link Margin	Total up and down link margins greater than +3dB. Minimum ground station elevation angle is 5o	Complies, currently +7dB margin (4dB over required minimum)	Analysis and Test	Antenna Pattern Test and Link Budget Analysis
68	3.1.2.5.3.5	Loss Allowance	Less than 1.0 dB Polarization losses and 3.0dB passive ground losses to be accommodated	Complies	Analysis	Included in Link Budget Calculations
69	3.1.2.5.3.6	Uplink Activation	Spacecraft receiver activated by presence of uplink signal	Complies, receiver is on all the time	Test	Spacecraft Functional Test
70	3.1.2.5.3.7	Uplink Performance as a Function of Spacecraft Attitude	Spacecraft capable of receiving commands at any orientation including tumbling at 2.5 degrees/sec	Complies	Analysis and Test	Antenna Pattern Test and Link Budget Analysis
71	3.1.2.5.3.8	Automatic Operations	Spacecraft capable of receiving and storing uplinked commands for execution at a later time	Complies	Test	Spacecraft IST

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
72	3.1.2.5.4	Downlink Communications	Spacecraft downlink antenna to generate sufficient EIRP to transmit data to the ground station	Complies	Analysis and Test	Antenna Pattern Test and Link Budget Analysis
73	3.1.2.5.4.1	Downlink Frequency	Telemetry frequency at 2275.300 MHz	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
74	3.1.2.5.4.2	Downlink Data Rates	Mode 1 downlink data rate at 8.000 Kbits/sec and Mode 2 downlink data rate at 2.048 Mbits/sec	Complies	Test	Spacecraft to Chantilly and NASA DSN Compatibility Test
75	3.1.2.5.4.3	Bit Error Rate for Uncompressed Data	Telemetry BER less than 1x10-6 more than 95% or the time	Complies	Analysis and Demonstration	Link Budget Analysis and Spacecraft Functional Test
76	3.1.2.5.4.4	Bit Error Rate for Compressed Data	Telemetry BER less than 1x10-9 more than 95% or the time	Complies	Analysis and Demonstration	Link Budget Analysis and Spacecraft Functional Test
77	3.1.2.5.4.5	Link Margin	Total up and down link margins greater than +3dB. Minimum ground station elevation angle is 5o	Complies, currently +7dB margin (4dB over required minimum)	Analysis and Test	Antenna Pattern Test and Link Budget Analysis
78	3.1.2.5.4.6	Loss Allowance	Less than 1.0 dB Polarization losses and 3.0dB passive ground losses to be accommodated	Complies	Analysis	Included in Link Budget Calculations
79	3.1.2.5.4.7	Downlink Activation				
			Mode 1 and 2 not transmitted simultaneously	Complies	Test	Spacecraft Functional Test, Spacecraft to Chantilly and NASA DSN Compatibility Test

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
			Mode 1 and 1 capable of being interleaved	Complies	Test	Spacecraft Functional Test, Spacecraft to Chantilly and NASA DSN Compatibility Test
			Mode 1 and 2 selectable by ground command	Complies	Test	Spacecraft Functional Test, Spacecraft to Chantilly and NASA DSN Compatibility Test
80	3.1.2.5.4.8	Downlink Performance as a Function of Spacecraft Attitude	Communications performance must be satisfied at off Nadir positions of Pitch +/- 22o, Roll +/- 22o , Yaw any angle	Complies	Analysis and Test	Antenna Pattern Test and Link Budget Analysis
81	3.1.2.6	Command Processing	Title Only			
82	3.1.2.6.1	Command Execution	Stored Commands loaded into memory, time-tagged for execution in synchronization with spacecraft clock referenced to on-board time	Complies	Test	Spacecraft Functional Test
83	3.1.2.6.2	Commands Verification	All real-time and stored commands to be verified prior to execution	Complies	Test	Spacecraft Functional Test
84	3.1.2.6.3	Types of Stored Commands	Provision made for absolute and relative timed commands	Complies	Test	Spacecraft Functional Test
85	3.1.2.6.4	Onboard Command Memory	DMS to provide command memory for 72 hours of autonomous operations	Complies	Test	Spacecraft Functional Test

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
86	3.1.2.6.5	Onboard Memory Loads	Provision made for up or down loading of RAM or ROM memory. Sufficient buffer to compare ground loads can be compared to their load images before transfer to active memory	Complies	Test	Spacecraft Functional Test
87	3.1.2.6.6	Uplinking of Stored Commands	Spacecraft shall accept commands at any time	Complies	Test	Spacecraft Functional Test
88	3.1.2.6.7	NO-OP Commands	Spacecraft shall provide NO-OP commands for telemetry verification	Complies	Test	Spacecraft IST
89	3.1.2.6.8	Synchronous Command Execution	Commands from all sources to execute without interference from each other	Complies	Test	Spacecraft Functional Test
90	3.1.2.7	Data Acquisition, Processing, and Storage	Definition Only			
91	3.1.2.7.1	Data Sampling	Spacecraft shall be capable of sampling analog, digital or discrete data	Complies	Test	Spacecraft IST
92	3.1.2.7.2	Payload Data Acquisition	Title Only			
93	3.1.2.7.2.1	Minimum Daily Data Quantity	Spacecraft to be able to store the combined sum of HSI, LEISA, UCB and Technology Demo data. The sum shall be greater than or equal to 1 Gbit per TRW working day when tasked	Complies	Test and Simulations	Final Integrated Systems Test

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
94	3.1.2.7.2.2	Longest Continuous Data Acquisition Period	Spacecraft shall meet sensor boresight control and knowledge as specified in D22891	Complies	Test and Simulations	Spacecraft Functional Test, Spacecraft Alignments and ACS Software Code simulations
95	3.1.2.7.2.3	Minimum Functional Data Acquisition Frequency	Spacecraft may be able to collect data from any primary payload once per orbit	Complies	Test	Final Integrated Systems Test
96	3.1.2.7.3	On-Board Data Storage Capacity	Spacecraft capable of storing 2Gbits of data at EOL	Complies, spacecraft has 4 Gbit of memory capacity at BOL	Test	Spacecraft Functional Test
97	3.1.2.7.4	Maximum Storage Rate	Spacecraft to accommodate data rates to the SSR up to 440 Mbps	Complies	Test	Spacecraft Functional Test
98	3.1.2.7.5	Stored Data Playback	Spacecraft to be capable of stored data playback with real-time data at he Mode 2 downlink rate	Complies	Test	Spacecraft Functional Test
99	3.1.2.7.6	Data Time Tagging	Spacecraft computer to receive time synchronization pulses from GPS and update the spacecraft clock with GPS time	Complies	Test	Spacecraft Functional Test
100	3.1.2.7.6.1	Accuracy of Time Broadcast	Time accuracy to be within 1 millisecond (3 sigma)	Complies	Test	Spacecraft Functional Test
101	3.1.2.7.6.2	Payload Data Time-Tag Accuracy	HSI data to be timetagged to an accuracy of 2 millisecond relative to GPS time	Complies	Test	Spacecraft Functional Test
102	3.1.2.7.7	Data Compression	Spacecraft shall be capable of compressing HSI and LEISA data by at least 2:1	Complies	Test	Final Integrated Systems Test
103	3.1.2.8	Fault Isolation	Title Only			

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
104	3.1.2.8.1	Pre-Launch Fault Isolation	Spacecraft to provide sufficient telemetry and test points to provide fault isolation capability during ground operations	Complies	By Design	
105	3.1.2.8.2	On-Orbit Fault Isolation	Spacecraft shall provide telemetry to permit proper selection of redundant units and command override of autonomous switching functions	Complies	Test	Spacecraft Functional Test
106	3.1.3	Physical Characteristics	Title Only			
107	3.1.3.1	Spacecraft Weight	Maximum spacecraft weight 850 lb.. LMSC separation ring 11.3 lb. max. Maximum spacecraft separated weight 861.3 lb.	Complies	Test	Weight and Mass properties measurements
108	3.1.3.2	Spacecraft Mass Properties	Spacecraft center of mass compatible with LLV	Complies	Analysis Test	SR4-047 Weight and Mass properties measurements
109	3.1.3.3	Spacecraft Dimensional Limitations	Spacecraft stowed configuration compatible with LLV static and dynamic envelopes	Complies	Analysis	Coupled Loads Analysis
110	3.1.4	Reliability and Mission Life	Spacecraft Bus 0.9 @ 3 years Spacecraft Bus 0.8 @ 5 years Spacecraft + HSI 0.7 @ 5 years	Complies	Analysis	D22890 Reliability Allocations Document
111	3.1.5	Maintainability	Spacecraft shall accommodate ground maintenance or repairs	Complies	N/A	By Design
112	3.1.6	Environmental Conditions	Ground Segment availability 0.95 during spacecraft flight operations	Complies	N/A	By Design

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
113	3.1.7	Transportation and Storage	Spacecraft and ground segment equipment shall allow for road or air transportation. Shipping container to provide protection from contamination and record maximum environments	Complies	Analysis	Various design documentation
114	3.2	Spacecraft Subsystem Requirements	Title Only			
115	3.2.1	Structures and Mechanisms Subsystem	Responsibility of Structures Subsystem Manager			
116	3.2.2	Thermal Control Subsystem	Responsibility of Thermal Subsystem Manager			
117	3.2.3	Electrical Power and Distribution Subsystem (EPDS)	Responsibility of EPS Subsystem Manager			
118	3.2.4	Guidance Navigation and Control Subsystem	Responsibility of GN&C Subsystem Manager			
119	3.2.5	Orbit Adjust Subsystem (OAS)	Responsibility of OAS Subsystem Manager			
120	3.2.6	Data Management Subsystem (DMS)	Responsibility of DMS Subsystem Manager			
121	3.2.7	Flight Software Subsystem	Responsibility of Software Subsystem Manager			
122	3.3	Payloads and Technology Demos	Title Only			
123	3.3.1	Hyperspectral Imager (HSI)	Responsibility of HSI Instrument Manager			

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
124	3.3.2	Integrated Linear Etalon Imaging Spectral Array (LEISA) and Optical Pointing Assembly	Collect spectrally resolved sunlit earth radiance image data in near infrared to short wave infrared (near IR - SWIR) bands with long, broad swath regions near or far from the SSTI ground track	Complies	Test	LEISA Unit level performance tests
125	3.3.3	Ultraviolet Cosmic Background (UCB) Spectrometer	Collect spectrally resolved photon count data along sidereal directions continually over multiple orbits during eclipse to construct a sky map-spectrum of the diffuse extreme ultraviolet cosmic background.	Complies	Test	UCB Unit level performance tests
126	3.3.4	Payload Support Technology Demonstrations and Equipment	Description Only			
127	3.3.4.1	Pulse Tube Cryocoolers	Provide cryogenic cooling for HSI and LEISA sensor units	Complies	Test	HSI and UCB Unit level performance tests
128	3.3.4.2	Optical Pointing Assembly (OPA)	Provide LEISA with expanded field of regard without spacecraft attitude variations	Complies	Test	Spacecraft IST
129	3.3.4.3	Payload Electronics Assembly (PEA)	Support payload instruments by providing the electronics for the cryocoolers, the OPA and the magnetically suspended reaction wheel	Complies	Test	HSI Test bed and Spacecraft IST

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
130	3.3.4.4	Data Compression Electronics and Software for Lossless and Lossy Data Compression	Lossless and lossy data compression techniques shall be demonstrated on-orbit. Compression ratios > 2:1, selectable by ground command, shall be demonstrated	Complies	Test	Spacecraft IST
131	3.3.4.5	Fiber Optic Data Bus (FODB)	Demonstrate the capability for transferring data from the HSI to the Data Management Subsystem at rates sufficient to support the maximum output rates of the HSI.	Complies	Test	Spacecraft IST
132	3.3.4.6	Solid State Recorder (SSR)	Store > 2 Gbits of data at the end of mission life	Complies, 4 Gbits capacity exists at BOL	Analysis, Test	HSI Test bed and Spacecraft IST
133	3.3.4.7	Recorder Interface Module (RIM)	Provide MIL-STD-1553B, wire and FODB interfaces from spacecraft payloads to the Solid State Recorder	Complies	Test	Spacecraft IST
134	3.3.5	Independent Technology Demonstrations	Description Only			
135	3.3.5.1	Global Positioning System (GPS) Attitude Determination	Provide the ability to determine spacecraft attitude knowledge to within 0.15 degrees (1 sigma value) by processing GPS obtained data. GPS time, position and velocity shall also be used to support payload data collection	Complies	Test	Spacecraft IST

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
136	3.3.5.2	Magnetically Suspended Reaction Wheel	Demonstrate the capability of the device to generate attitude corrections to a spacecraft by measuring the on-orbit torques generated by the reaction wheel	Complies	Test	Spacecraft IST
137	3.3.5.3	Microcosm Orbit Control Kit	Demonstrate autonomous orbit altitude maintenance by providing periodic maneuver (delta V) advisory commands for ground evaluation.	Complies	Test	Spacecraft IST
138	3.3.5.4	Cascade Solar Cell Experiment	Measure output performance of cascade cells with standard and infrared reflecting coverglass on-orbit	Complies	Test	Spacecraft IST
139	3.3.5.5	Amorphous Silicon Solar Cell Experiment	Measure output performance of amorphous silicon thin film solar cells on-orbit	Complies	Test	Spacecraft IST
140	3.3.5.6	Gallium Arsenide Solar Cell Experiment	measure output performance of Gallium Arsenide solar cells on-orbit	Complies	Test	Spacecraft IST
141	3.3.5.7	Metal Matrix Composite Thermal Strap	Demonstrate the capability to transfer heat from the generating source to the spacecraft radiator	Complies	Test	Spacecraft Thermal Vacuum Test
142	3.3.5.8	Spacecraft Loads and Acoustics Measurement (SLAM)	Measure acceleration and acoustic loads during launch and on-orbit operations	Complies	Test	Spacecraft IST and Vibration Test
143	3.3.5.9	Micro-machined Accelerometers	Measure acceleration and acoustic loads during launch and on-orbit operations	Complies	Test	Spacecraft IST and Vibration Test

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
144	3.3.5.10	Radiation Environment Measurement Experiment	Measure the linear energy transfer (LET) spectrum as a function of orbital position (latitude, longitude and time) in order to validate radiation transport codes and to improve LEO radiation environment models	Complies	Test	Spacecraft IST
145	3.3.5.11	Enhanced Attitude Control System Experiment	Evaluate the feasibility of implementing a high bandwidth, high performance Attitude Control System for the SSTI Spacecraft in the Normal Mode	Complies	Test	Spacecraft IST
146	3.3.5.12	Cloud and Feature Editing Experiment	Demonstrate the ability to identify clouds and terrestrial features (such as snow cover) at pixel level in post-flight processing of HSI and/or LEISA data	Complies	Not Applicable	This is a post processing experiment
147	3.3.5.13	Wide Field of View Star Tracker (WSTA)	Demonstrate the potential for supporting a high-accuracy, lightweight gyroless attitude control system	Complies	Test	Spacecraft IST
148	3.4	Ground Support Equipment	This Section Exempt from Verification Requirements Matrix			
149	3.5	Design and Construction	Title Only			
150	3.5.1	Parts, Materials and Processes	Description Only			
151	3.5.1.1	Electrical, Electronic, and Electromechanical (EEE) Parts	Parts to meet design life and reliability requirements in D22876 Mission Assurance Plan	Complies	Inspection	Parts lists approved by Mission Assurance

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
152	3.5.1.2	Fasteners	Flight hardware fasteners procured in accordance with D04740 Standard Quality Assurance Requirements for Procured Items	Complies	Inspection	Incoming Inspection
153	3.5.1.3	Materials Selection Requirements	Materials to be selected to consider space and contamination effects	Complies	Inspection	Incoming Inspection
154	3.5.1.3.1	Compliant Materials and Processes	Definition Only			
155	3.5.1.3.2	Noncompliant Materials and Processes	Definition Only			
156	3.5.1.3.3	Conventional Application	Definition Only			
157	3.5.1.3.4	Non-conventional Application	Definition Only			
158	3.5.1.3.4	Polymeric Materials	Materials selected must be resistant to atomic oxygen corrosion	Complies	Inspection	Incoming Inspection
159	3.5.1.3.5	Flammability and Toxic Offgassing	Guidelines for rating materials for flammability and toxic offgassing			
160	3.5.1.3.6	Vacuum Outgassing	Guidelines for rating materials for vacuum outgassing			
161	3.5.1.3.7	Shelf Life Controlled Items	Limited (5 year) shelf life materials to be reported to Mission Assurance Manager	SSTI has no limited shelf life items		

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
162	3.5.1.3.8	Inorganic Materials	Only materials with high resistance to stress corrosion cracking shall be used. Welding to be minimized. Ceramics and Glass not to be used in structural applications	Complies	By Design	[redacted]
163	3.5.1.3.9	Use of Dissimilar Metals	Use of dissimilar materials discouraged. If dissimilar materials are used, an appropriate finishing system shall be used	Complies	By Design	[redacted]
164	3.5.1.3.10	Lubrication	Lubricants to be used based on test results that confirm suitability to the chosen application	Complies	By Design	[redacted]
165	3.5.1.4	Process Selection Requirements	Manufacturing Processes to be selected such that material integrity is maintained and physical property changes are well understood.	Complies	By Design	[redacted]
	3.5.1.4a		Vendors to submit a materials and process specification list (MPSL) to TRW for approval	Complies	Inspection	Inspection of MPSL Lists from Vendors
166	3.5.2	Electromagnetic Radiation	Spacecraft to be designed to the requirements contained in the SR1-0125 Electromagnetic Interference and Susceptibility and Requirements Specification	Complies	Test	Spacecraft EMC Test and Selected Component Level EMC Tests
167	3.5.3	Identification, Nameplates and Marking	Description of Identification Tag contents	Complies	Inspection	Various final inspections

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
168	3.5.4	Workmanship	Equipment to be manufactured so that finished items are of sufficient quality to ensure reliable, safe operation	Complies	Inspection	Various Final Inspections
169	3.5.5	Interchangeability	Components with the same part number shall be interchangeable in form, fit, function, reliability and qualification status	Complies	TRW Q/A procedures	Various final inspections
170	3.5.6	Safety	Comply with WRR 127-2 safety requirements	Complies	Analysis and procedures	D22886 Accident Risk Assessment report. Launch Site procedures
	3.5.6a		If a failure from a part made from low or moderate resistance to stress corrosion cracking could result in a catastrophic or critical hazard, a material Usage Agreement shall be submitted to the Mission Assurance Manager	Complies	By Design	
171	3.5.7	Grounding	Spacecraft design to conform to the grounding requirements in SR1-0125	Complies	Inspection	Electrical Harness final inspection. Spacecraft Final Assembly Inspection
172	3.6	Environmental Design Requirements	Title Only			
173	3.6.1	Design and Test Environments	Spacecraft and components to be designed to withstand the environments in EV2-099 and EV1-034	Complies	Test	Component and Spacecraft Level Environmental Tests

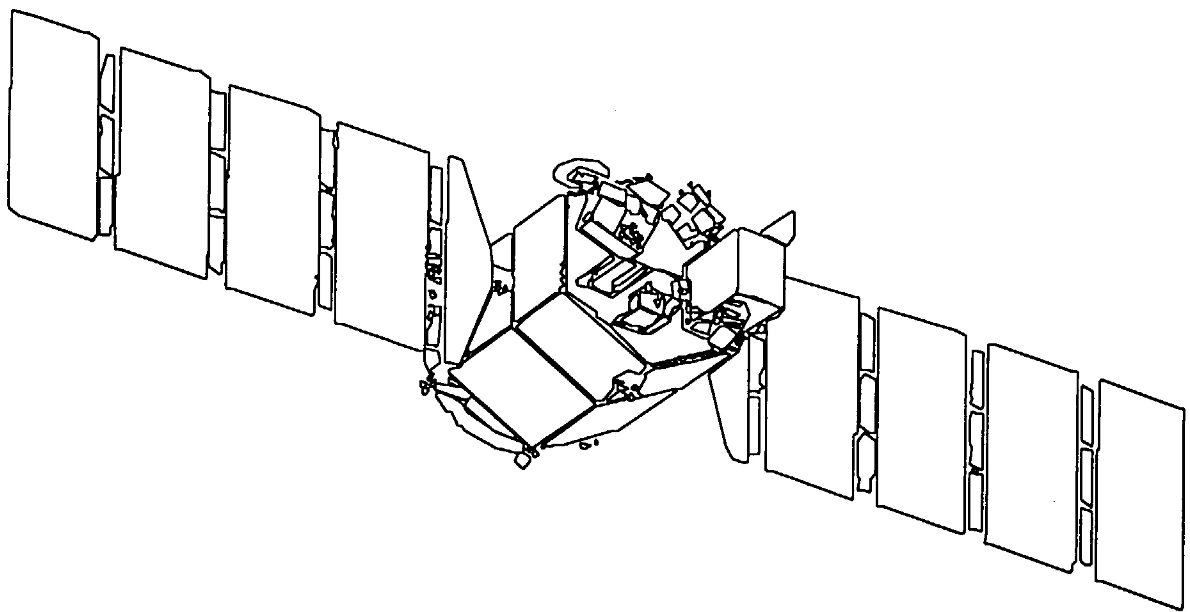
SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
174	3.6.2	Transportation, Shipping, and Handling Environment	Environments experienced during shipping and handling to be less than launch conditions	Complies	Inspection	Incoming Inspection of trip accelerometers of shipped flight equipment
175	4	QUALITY ASSURANCE PROVISIONS	Title Only			
176	4.1	General	Quality methods and testing to be performed din accordance with D22876 Mission Assurance Plan	Complies	Procedures and inspections	Various test procedures and Inspections
177	4.1.1	Quality Conformance and Verification Test Requirements				
	4.1.1a		Components to be tested to the environmental requirements contained in EV2-099	Complies	Test	Component level environmental tests
	4.1.1a		Spacecraft to be tested to the environmental requirements contained in EV1-034 and the D22877 System Integration and Test Plan	Complies	Test	Spacecraft level environmental tests
	4.1.1a		Compatibility between the spacecraft and NASA Ground Network shall be demonstrated per STDN No. 408.1	Complies	Test	Spacecraft to NASA DSN Compatibility Test
178	4.1.1	Responsibility For Tests	Definition Only			
179	4.1.2	Failure Criteria	Definition Only			

SSTI SY26-005 Spacecraft Specification Requirements Verification Matrix

No.	Para.	Paragraph Title	Requirement	Capability	Verification Method	Planned Event or Document containing analysis or test results
180	5	PREPARATION FOR DELIVERY	All elements of the spacecraft or its components shall be protected from degradation from environments during shipping , handling or storage	Complies	Inspection	Inspection of configuration to be shipped

Small Satellite Technology Initiative
(SSTI Lewis Spacecraft Program)



System Critical Design Audit (CDA)

January 17-19, 1995

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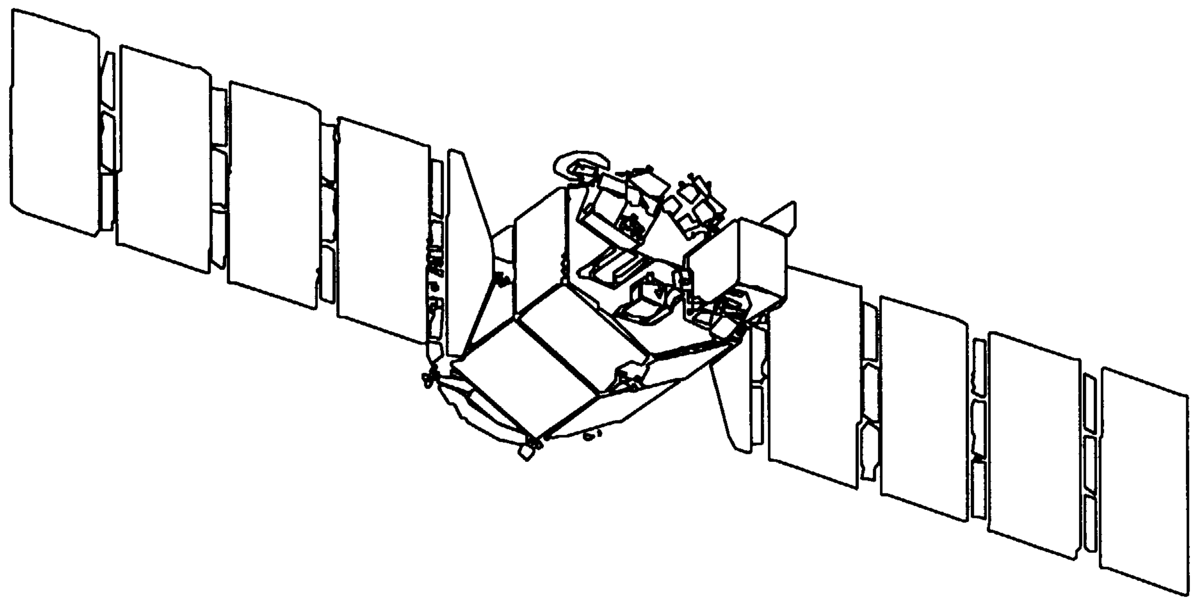
Small Satellite Technology Initiative
(SSTI Lewis Spacecraft Program)



System Critical Design Audit (CDA)

January 17-19, 1995

Book 2 of 3

SSTI-LEWIS CDA AGENDA, DAY 1
TUESDAY, 17 JANUARY 1995

TIME	TOPIC	PRESENTER
10:00 - 10:10	Welcome & Introduction	Watkins/Sabelhaus
10:10 - 10:20	Program Overview	Marshall
10:20 - 10:50	Technical Overview	Biber/Taylor
	SYSTEM REQUIREMENTS	
10:50 - 11:10	Performance	Taylor
11:10 - 11:40	Verification	Belte
11:40 - 12:10	Mission Assurance	Niemela
12:10 - 13:00	Lunch	
	SCIENCE & COMMERCIAL APPLICATIONS	
13:00 - 13:15	Overview	Pearlman
13:15 - 13:45	Mission Data Management System	Witcher
13:45 - 14:05	Education	Woods, M.
14:05 - 14:25	Applications Development	Pearlman
14:25 - 14:40	Data Policy	Watkins
	GROUND SEGMENT	
14:40 - 14:50	Overview	Sarina
14:50 - 15:20	Requirements	Berman
15:20 - 15:35	Break	
15:35 - 16:05	CDRS Design	Taylor (Harris)
16:05 - 16:35	SOCC Design	Berman
16:35 - 17:15	Mission Operations	Zion

SSTI-LEWIS CDA AGENDA, DAY 2
WEDNESDAY, 18 JANUARY 1995

TIME	TOPIC	PRESENTER
	SPACECRAFT INTEGRATION, TEST, & LAUNCH	
8:30 - 8:45	Design Summary	Woods, D.
8:45 - 9:30	Mechanical Design Integration	Norden
9:30 - 10:15	Electrical Design Integration	Woods, D.
10:15 - 10:30	Break	
10:30 - 12:00	System Integration & Test	Brooks
12:00 - 12:45	Lunch	
12:45 - 13:30	Launch Interface & Operations	Turner/Desilets
	PAYLOADS & TECHNOLOGY DEMONSTRATIONS	
13:30 - 13:45	Overview	Conte
13:45 - 14:30	HSI	Marmo
14:30 - 15:00	LEISA	Reuter
15:00 - 15:15	Break	
15:15 - 15:45	UCB	Edelstein
15:45 - 16:00	Recorder Interface Module (RIM)	Hayes
16:00 - 16:10	GEM/SLAM	Luers
16:10 - 16:20	Multi-junction GaAs Solar Cells	Slifer
16:20 - 16:30	Amorphous Silicon Solar Cells	Starritt
16:30 - 16:40	ASCE Electronics Design	Larrick
16:40 - 16:55	GPS Attitude Determination	Bauer
16:55 - 17:05	Metal Matrix Heat Strap	Casto
17:05 - 17:15	Micromachined Accelerometers	Conte

SSTI-LEWIS CDA AGENDA, DAY 3
THURSDAY, 19 JANUARY 1995

TIME			TOPIC	PRESENTER
			PAYLOADS & TECH DEMOS (CONTINUED)	
8:30	-	8:40	Lossless Data Compression Module	Fong
8:40	-	8:50	Lossy Data Compression	Yeh
8:50	-	9:00	GPC	Shinn
9:00	-	9:15	Cloud and Feature Editing	Davis
9:15	-	9:25	WFOV Star Tracker	Parry
9:25	-	9:35	Mag. Suspended Reaction Wheel	Gerson
9:35	-	9:45	MOCK	Gerson
9:45	-	9:55	Enhanced ACS	Maghami
9:55	-	10:05	On-Orbit ID	Elliott
10:05	-	10:20	PEA/OPA/Cryocoolers	Gerson
10:20	-	10:25	New Experiments	Conte
10:25	-	10:30	Summary	Conte
10:30	-	10:45	Break	
			SPACECRAFT BUS	
10:45	-	11:00	Overview	Biber
11:00	-	11:30	Structure & Mechanisms	Barrett
11:30	-	11:50	Thermal Control	Biber
11:50	-	12:20	Propulsion	Joseph
12:20	-	13:15	Lunch	
13:15	-	13:45	Electrical Power & Distribution	Starritt
13:45	-	14:15	GN&C	Parry
14:15	-	15:15	Data Management Subsystem	Almeida
15:15	-	15:30	TT&C	Schall
15:30	-	15:45	Break	
15:45	-	16:30	Spacecraft Software	Stafa/Smith
			CLOSURE	
16:30	-	16:50	Program Milestone Summary	Lane
16:50	-	17:00	Closing Remarks	Watkins/Sabelhaus

Spacecraft Design Integration

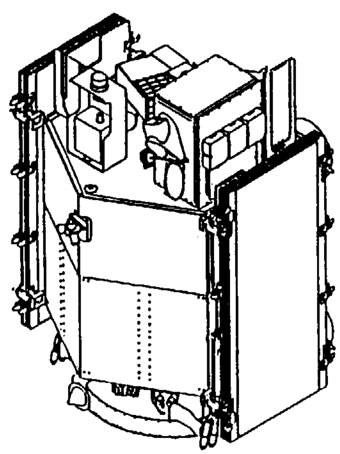
Dick Woods

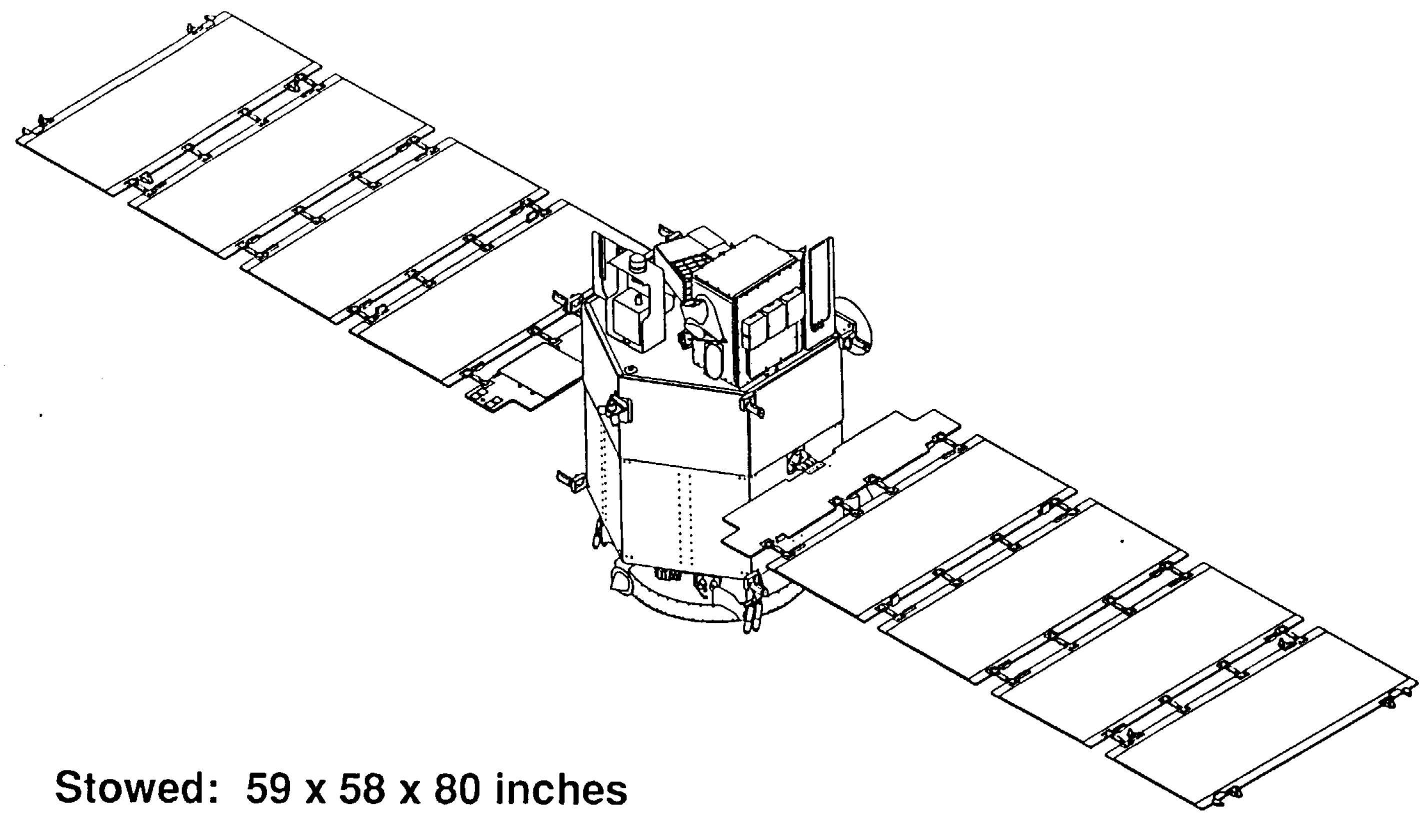
SDI Organization

SDI consists of the following major elements

- Mechanical Design Integration (MDI)
- Electrical Design Integration (EDI)
- Mass Properties
- Payload Thermal Design Integration
- Interface Control Documents
- Contamination Control
- System Dynamics
- System Architecture

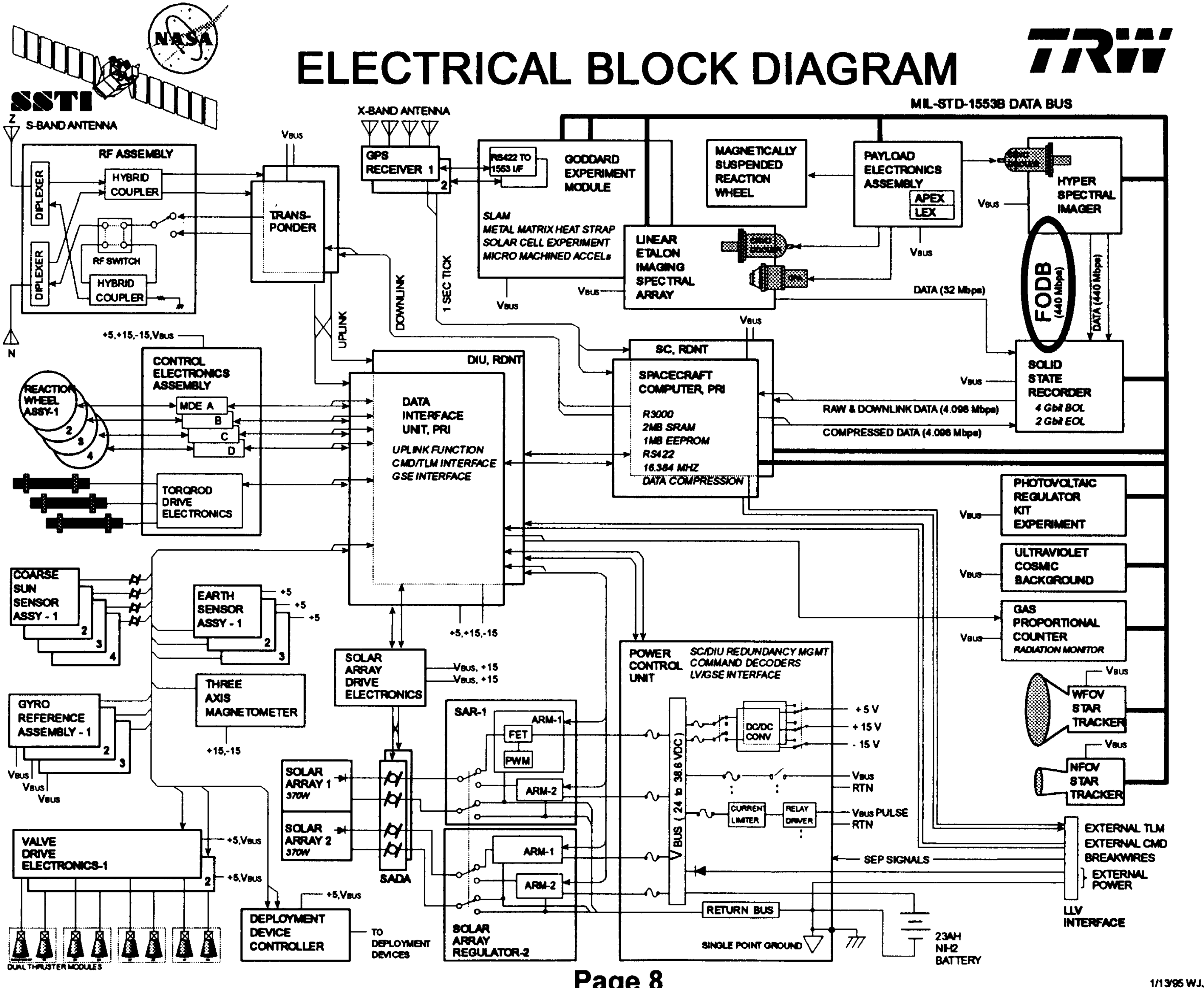
Integrated Design Characteristics



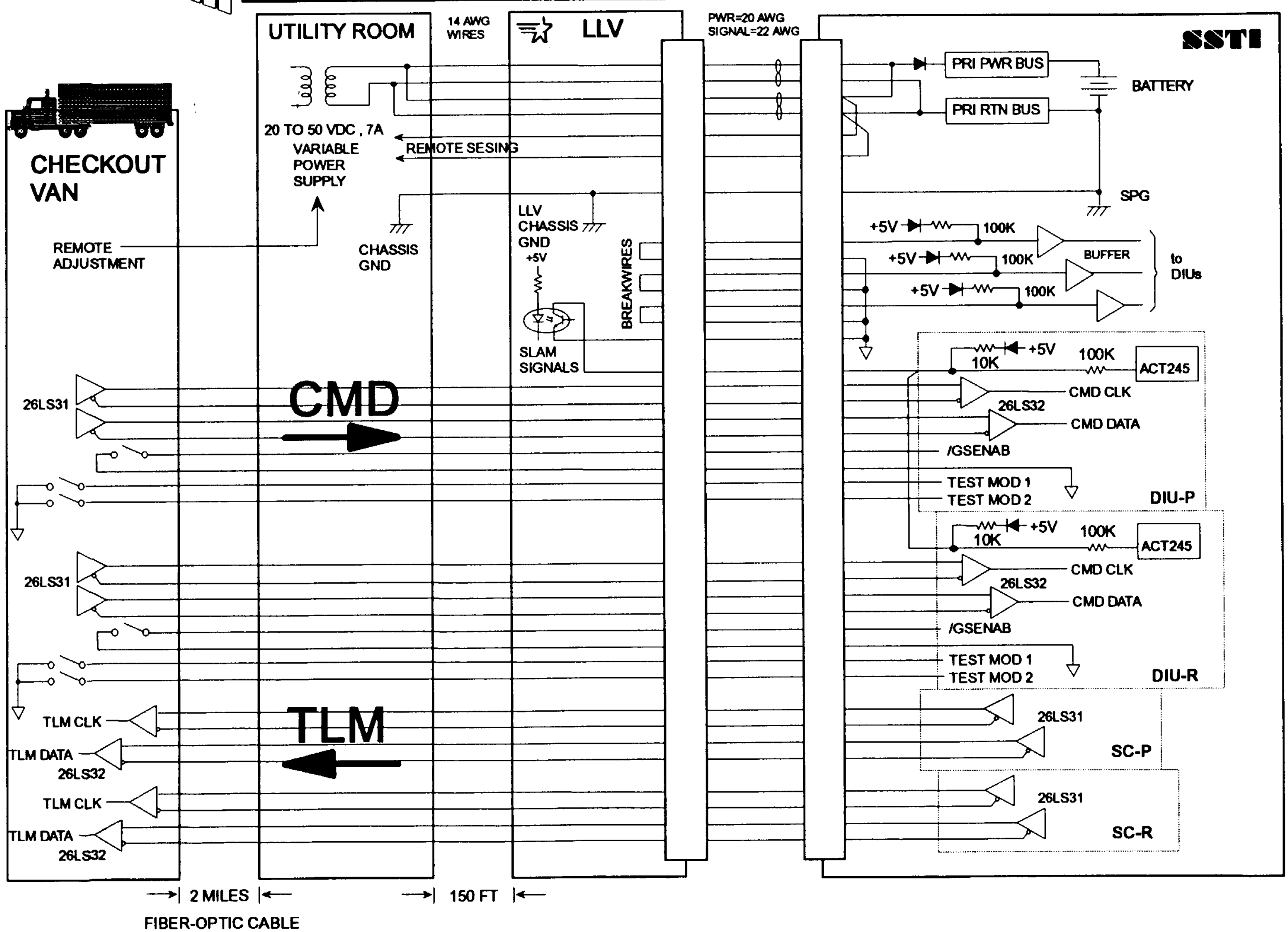


Stowed: 59 x 58 x 80 inches
Deployed: 327 x 59 x 80 inches
Weight: 850 lbs
Power: 740 W EOL (5 yrs)
Orbit: 523km x 94.7 degrees

ELECTRICAL BLOCK DIAGRAM



LLV INTERFACE



Spacecraft Weight Allocation

• Core Bus	239.8 kg
• Bus Technology Demos	25.3
• Payload Support Equipment	9.6
• Payload Instruments	65.1
• Launch Vehicle Adapter	5.1
– Spacecraft Launch Weight (dry)	344.9
• Propellant	42.1
– Spacecraft Launch Weight (wet)	387.0
• LLV Launch Capability	390.7
• Spacecraft Margin	3.7 kg
– Includes Lewis and JPL Experiments	

Spacecraft Weight Allocation

EQUIPMENT		WEIGHT(KG)	WEIGHT (KG)	WT(KG)	WT(KG)	HERITAGE	MATURITY
		ESTIMATE	CONT'CY (%)	CONT'CY	INCL CONT		
CORE BUS		**217.6**	10.2	22.1	239.8		
STRUCTURE		60.2	13.9	8.4	68.5		
THERMAL		4.0	25.0	0.9	4.9		
PROPULSION		15.8	2.9	0.5	16.2		
ELECTRICAL POWER		63.9	9.6	6.1	70.1		
DISTRIBUTION HARNESS		18.8	25.0	4.7	23.5		
GUIDANCE, NAV. & CONTROL		33.5	2.3	0.8	34.2		
DATA MANAGEMENT		21.5	3.9	0.8	22.3		
BUS TECHNOLOGY DEMOS		**23.5**	7.7	1.8	25.3		
PAYLOAD SUPPORT EQPMT.		**9.1**	5.0	0.5	9.6		
PAYLOAD INSTRUMENTS		**58.2**	11.8	6.9	65.1		
HSI		31.3	16.3	5.1	36.4		
LEISA		6.4	4.8	0.3	6.7		
UCB		18.0	5.0	0.9	18.9		
DECISIONS PENDING		2.5	23.0	0.6	3.1		
LLV1 ADAPTER		**5.1**		0.0	5.1		
BALLAST		**0.0**			0.0		
SC LAUNCH WEIGHT (DRY)		**313.6**	10.0	31.3	344.9		
PROPELLANT BUDGET		**42.1**			42.1		
Altitude correction		0.6					
Inclination error correction		2.6					
Orbit Transfer		24.4					
ACS momentum unloading		0.0					
Orbit Maintenance		2.0					
Orbit Maintenance		11.2					
Ullage		1.0					
Pressurant		0.3					
SC LAUNCH WEIGHT (WET)		**355.6**		31.3	387.0		
LLV1 LAUNCH CAPABILITY(861.3 LBS)					390.7		
SPACECRAFT MARGIN					3.7		

Spacecraft Weight Allocation

EQUIPMENT	QTY	WEIGHT(KG) ESTIMATE	WEIGHT(KG) CONT'CY (%)	WT(KG) CONT'CY	WT(KG) INCL CONT	HERITAGE	MATURITY
STRUCTURE		**60.1**	**13.9**	**8.3**	**68.4**		
RING/BOOSTER I/F	1	2.3	10.0	0.2	2.5	AB600	Mod for LLV
BAT./PROP. MODULE (BPM)	1	14.1	10.0	1.4	15.5	AB600	Mod for SSTI
AVIONICS MODULE(AM)	1	16.9	15.0	2.5	19.4	AB600	Mod for SSTI
PAYLOAD MODULE	1	19.1	15.0	2.9	22.0	AB600	Mod for SSTI
RESTRAINT SYSTEM	1	4.8	15.0	0.7	5.5	BP	Mod for SSTI
MISC BRACKETS	1	2.9	20.0	0.6	3.5	AB600	Mod for SSTI
THERMAL		**4.0**	**25.0**	**0.9**	**4.9**	AB600	Mod for SSTI
PROPULSION		**15.8**	**2.9**	**0.5**	**16.2**		
PROPELLANT TANK	1	6.8	1.0	0.1	6.9	New	2 DVTs built
FILL & DRAIN VALVES	2	0.2	1.0	0.0	0.2	TDRS, TOMS	Off-the-shelf
PRESSURE TRANSDUCER	1	0.5	1.0	0.0	0.5	TDRS, DSP	Off-the-shelf
FILTER	1	0.3	1.0	0.0	0.3	SPS	Off-the-shelf
DUAL THRUSTER MODULE	4	5.2	1.0	0.1	5.3	TOMS, GPS	Off-the-shelf
ISOLATION VALVE	2	0.5	1.0	0.0	0.5	TDRS, DSP	Off-the-shelf
INTERCONNECTING LINE ASSEMBLY	1	0.6	15.0	0.1	0.7	SSTI-Specific	N/A
MOUNTING HARDWARE	1	0.9	15.0	0.1	1.0	SSTI-Specific	N/A
OAS INSULATION	1	0.5	20.0	0.1	0.6	SSTI-Specific	N/A
HEATERS	SET	0.3	1.0	0.0	0.3	SSTI-Specific	N/A
ELECTRICAL POWER		**63.9**	**9.6**	**6.1**	**70.1**		
PCU	1	9.3	5.0	0.5	9.8	TOMS	add 2 slices
DEPLOYMENT DEVICE CONTROLLER	1	1.2	1.0	0.0	1.2	TOMS	Off-the-shelf
SOLAR ARRAY REGULATOR ELECTRONICS	2	5.0	5.0	0.3	5.3	TOMS	add 1 relay
CPV NiH2 BATTERY	1	24.5	10.0	2.5	27.0	BP	Major Mod.
SOLAR ARRAYS	2	24.0	12.3	2.9	26.9	BP, STEP	Major Mod.
YOKES	2	1.7	15.0	0.3	2.0	BP	Mod for SSTI
PANEL SUBSTRATES	8	13.6	15.0	2.0	15.7	STEP	Mod for SSTI
ELECTRICAL PANELS	8	8.7	7.5	0.6	9.3	SSTI-specific	Std. Si panels

Spacecraft Weight Allocation

EQUIPMENT		WEIGHT(KG)	WEIGHT (KG)	WT(KG)	WT(KG)	HERITAGE	MATURITY
		ESTIMATE	CONT'CY (%)	CONT'CY	INCL CONT		
DISTRIBUTION HARNESS		18.8	25.0	4.7	23.5		
DC HARNESS	1	18.2	25.0	4.6	22.8	TOMS	Major Mod.
RF HARNESS	1	0.6	25.0	0.2	0.8	TOMS	Major Mod.
GUIDANCE, NAV. & CTL.		33.5	2.3	0.8	34.2		
GYRO REFERENCE ASSY. (3)	3	4.5	1.0	0.0	4.5	TOMS	Off-the-shelf
TAM ELECTRONICS (1)	1	0.4	1.0	0.0	0.4	TOMS	Off-the-shelf
TAM SENSOR (1)	1	0.1	1.0	0.0	0.1	TOMS	Off-the-shelf
COARSE SUN SENSORS (4)	4	0.0	1.0	0.0	0.0	TOMS	Off-the-shelf
EARTH HORIZON SENSORS (3)	3	1.1	3.0	0.0	1.1	Iridium	In qual ?
REACTION WHEEL ASSY'S (4)	4	9.7	3.0	0.3	10.0	TOMS	Minor Mod
WHEEL MOTOR DRIVES (4)	4	3.0	1.0	0.0	3.0	TOMS	Off-the-shelf
TORQUER DRIVE ELEC'S (1)	1	0.3	1.0	0.0	0.3	TOMS	Off-the-shelf
MAGNETIC TORQUERS (3)	3	1.3	1.0	0.0	1.3	TOMS	Off-the-shelf
VALVE DRIVE ELEC'S (2)	2	4.5	1.0	0.0	4.6	TOMS	Off-the-shelf
SOLAR ARRAY DRIVE ASSY	2	4.0	1.0	0.0	4.0	STEP 0	Off-the-shelf
SOLAR ARRAY DRIVE ELEC'S (2)	2	1.2	1.0	0.0	1.2	Iridium ?	Off-the-shelf
NARROW FOV STAR TRACKER	1	3.4	7.5	0.3	3.6	IR&D	od. exist. des.
DATA MANAGEMENT		21.5	3.9	0.8	22.3		
ON BOARD COMPUTER (inc. DC/DC CONVERTER)	2	6.2	3.0	0.2	6.4	BP	Minor Mod
DATA INTEFACE UNIT	2	5.1	3.0	0.2	5.3	TOMS	Board mods.
RF ASSEMBLY	1	1.4	12.5	0.2	1.6	TOMS	Major Mod
GSTDN TRANSPONDER (5W RF output)	2	8.2	3.0	0.2	8.4	OMS, DSPSE	Minor Mods
S-BAND ANTENNA(OMNI)	2	0.6	12.5	0.1	0.7	sim. to STEP	Major Mod

Spacecraft Weight Allocation

		ESTIMATE	CONT'CY (%)	CONT'CY	INCL CONT		
BUS TECHNOLOGY DEMOS		23.4	8.3	1.9	25.3		
GPS ATT. DET.-ANTENNAS	4	0.4	5.0	0.0	0.4		
GPS ATT. DET.-RECEIVERS	2	1.8	5.0	0.1	1.9		
GPS PRE-AMPS	4	1.2	5.0	0.1	1.3		
METAL MATRIX HEAT STRAP	1	0.5	16.0	0.1	0.5		
MAG.-SUS. REACTION WHEEL	1	2.5	1.0	0.0	2.5		
WIDE FOV STAR TRACKER	1	3.2	10.0	0.3	3.5		
RADIATION MONITOR	1	2.5	10.0	0.3	2.8		
GODDARD ELECTRONICS MODULE	1	9.2	10.1	0.9	10.2		
CCA'S							
LVPS		1.2	10.0	0.1	1.4		
ESNX2		2.0	10.0	0.2	2.2		
ASCE		0.6	15.0	0.1	0.7		
LIESA		0.6	15.0	0.1	0.7		
DRAM		1.0	10.0	0.1	1.1		
CHARGE AMPS		0.3	25.0	0.1	0.4		
HARNESS		0.3	25.0	0.1	0.3		
HOUSING							
TOP		0.6	5.0	0.0	0.6		
BASE		1.0	5.0	0.1	1.1		
SIDE		0.4	1.5	0.0	0.4		
SIDE		0.5	5.0	0.0	0.5		
COVER FRONT		0.2	5.0	0.0	0.2		
COVER REAR		0.2	5.0	0.0	0.3		
FASTENERS		0.2	25.0	0.0	0.2		
SLAM SENSORS		0.5	1.0	0.0	0.5		
SINGLE/MULTI JUNCTION SOLAR CELL EXP. (GODDAR	1	0.2	10.0	0.0	0.3		
THIN FILM SOLAR CELL EXP (TRW) AMORPHORUS	1	1.4	10.0	0.1	1.5		
EQUIPMENT		WEIGHT(KG)	WEIGHT (KG)	WT(KG)	WT(KG)	HERITAGE	MATURITY

Spacecraft Weight Allocation

EQUIPMENT		WEIGHT(KG) ESTIMATE	WEIGHT (KG) CONT'CY (%)	WT(KG) CONT'CY	WT(KG) INCL CONT	HERITAGE	MATURITY
PAYLOAD SUPPORT EQPMT		**9.1**	**5.0**	**0.5**	**9.6**		
SOLID STATE RECORDER	1	5.5	5.0	0.3	5.8	IR&D, MDS	in detailed des.
PAYLOAD ELEC'S ASSY (incl shielding)	1	3.6	5.0	0.2	3.8	BP	mod. exis. des.
PAYLOADS		**58.2**	**11.8**	**6.9**	**65.1**		
HYPER SPECTRAL IMAGER		**31.3**	**16.3**	**5.1**	**36.4**		
SENSOR		23.0	15.0	3.4	26.4		
ELECTRONICS		8.3	20.0	1.66	9.97		
HCE		4.3	20.0	0.86	5.16		
HPE		3.5	20.0	0.70	4.21		
Cabling		0.5	20.0	0.10	0.60		
LEISA		**6.4**	**4.8**	**0.3**	**6.7**		
CRYOCOOLER		2.1	1.0	0.0	2.1		
SPECTROGRAPH		2.5	5.0	0.1	2.6		
OPA		0.8	1.0	0.0	0.8		
RADIATOR		1.0	15.0	0.2	1.2		
UCB		**18.0**	**5.0**	**0.9**	**18.9**		
SPECTROGRAPH		11.2	5.0	0.6	11.8		
ELECTRONICS		6.8	5.0	0.3	7.1		
DECISIONS PENDING		**2.5**	**23.0**	**0.6**	**3.1**		
LeRC/TRW Solar Array Power Processor Bus Demo		2.0	25.0	0.5	2.5	IR&D	schematics
JPL/TRW Advanced Packaging Technology Bus Demo		0.5	15.0	0.1	0.6	IR&D	MCM in fab

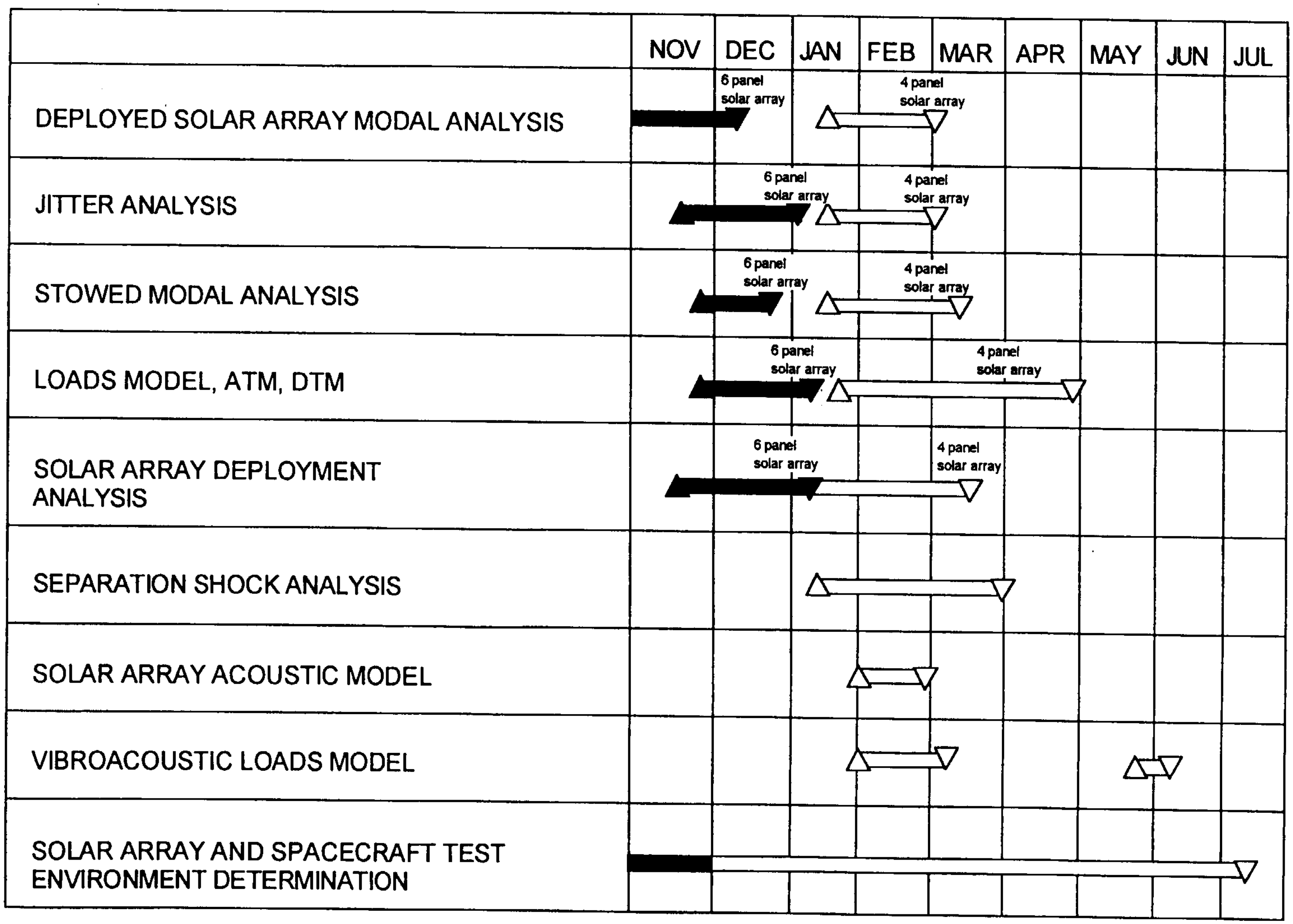
SDI Document Status
EDI

• EMC Control Plan/Spec	Sept 94
• Magnetic Moment Analysis	Dec 94
• Harness Diagram	Dec 94
• Reference Designators	Dec 94
• Fuse Document	Dec 94
• Power Allocations	Jan 95
• Command Allocations	Jan 95
• Telemetry Allocations	Jan 95
• System Interface Definition (SID)	Feb 95
• Electrical Interface Specification	Jun 95

SSTI

Dynamics

TRW



SSTI

Payload Dissipation and Temperature Requirements

TRW

	Power Dissipation ~ Watts		Acceptance Temperature (Normal Operation)		Non-Operating/ Turn-On temperature		Orbital Operation	
	Max	Min	Max	Min	Max	Min	Status	Timeline
LEISA								
Bench	8.8	7.3	30°C	0°C	40°C	-10°C	Off	Normally during eclipse or when not taking data.
FPA	.40	.25	88°K (A)	78°K (A)				
Cryocooler	--	--					On	Continuous.
Cold Head			83°K	73°K				
Baseplate	18.0	14.0	25°C	0°C	35°C	0°C		
OPA	5.4	2.0	61°C	-24°C	71°C	-29°C	Standby	Normally in low power mode.
UCB	7.1	4.6	45°C	-15°C	55°C	-25°C	On	Max power during 25 min of eclipse.
							Off	Any period.
Stack Tracker	13.4	9.8	45°C	- 5°C	55°C	-15°C		
NFOV							On	Continuous
WFOV							On	2 orbits/day.
Metal Matrix Heat Strap	1.7	.7	12°C (B)	-52°C (B)	N /A	N/A	On	1 hr. every 2 weeks.

(A) Nominal temperature design point is 78°K for the cryocooler.
FPA temperature is to be held with ± 1°K during data accumulation.

(B) Radiator temperatures.

ICDA-2 Action Items

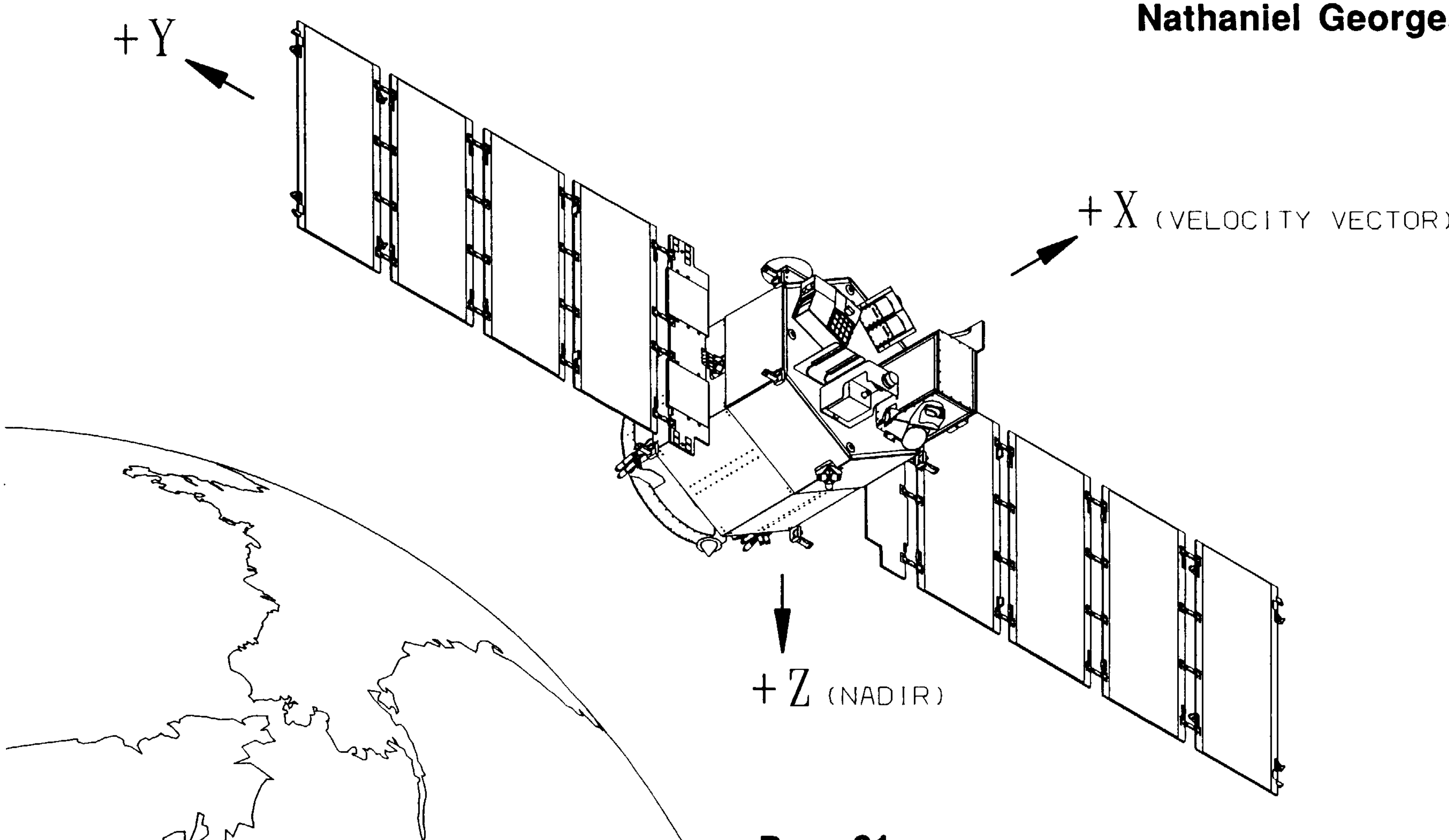
- Action Item 2-31A - Spacecraft Time Management
  - How does the GPS time tag enter the OBC??
  - Ans: Each GPS receiver is wired to the OBC DIM board as an interrupt.
  - These inputs are also cross-strapped to the backup OBC.
- Action Item 2-34A - OBC Memory Allocations
  - Where are the real time command sequences (RTCS) defined??
  - Ans: The RTCS are part of the Software Requirements Specification as an appendix.
  - They are printed as a separate document
  - TOMS has this document and we will use it as the starting point

Deployment Redundancy Management (ICDA-2 Action Item 2-15)

- Deployment Sequence Main Events
  - Separation
  - Time delay
  - Deploy solar array
  - Time delay
  - Enable ACS in Safe Haven mode
  - If sun acquisition times out, force OBC switch over
  - Set relay to indicate sun acquired
- During deployment, normal DMS, ACS and EPDS fault detection tests enabled
- During software initialization in backup OBC
  - Relay is checked for sun acquisition
  - If not, deployment sequence is repeated using the “B” side DMS and ACS equipment

Mechanical Design Integration

Brian Norden
Don Schmude
Nathaniel Georges



MDI Responsibilities

- The SSTI satellite configuration is defined and controlled through a 3D solid CATIA database. A configuration layout (L305581 see appendix) was generated to aid non CATIA users.

- Component level physical requirements (mechanical, electrical, and thermal) are defined and controlled within Interface Control and Source Control Drawings (ICD's, SCD's).

  - <u>Drawing Status:</u>

    12 released
    21 "in check" ready for release
    10 draft versions
     8 awaiting additional data
    51 total identified

- Six installation drawings have been identified and are currently scheduled in the March 95 - October 95 time frame.

Requirements Vs. Capabilities

Requirement	Source	Capability
Ø68.0 x 84.22 inch stowed dynamic envelope	Launch Vehicle	Meet by design.
Stowed C.G. within 2.5 inches of the X axis in the Y - Z plane.	Launch Vehicle	Meet by design.
Deployed C.G. within 2.0 inches of the X axis in the Y - Z plane.	ACS System	Meet by design.
Provide vehicle modularity	System	The spacecraft configuration provides mechanical and electrical modularity across the Battery / Propulsion Module, Avionics Module, and Payload module.
Equipment and payload mounting accommodations	System	Components are mounted on panels via embedded inserts. see dwg. L305581.
Equipment and payload accessibility / maintainability	System	The equipment and payloads are capable of being integrated, removed and replaced using standard methods. No special tools or procedures are required.
Harness routing and accessibility / maintainability	System	The harness is capable of being integrated and repaired using standard methods. No special tools or procedures are required.
Provide a unobstructed field of view for payloads and sensors	Instrument and Sensor ICD's	Field of View blockage / instrument limitations will be defined within Document (TBD) see field of view charts.

Requirements Vs. Capabilities

Requirement	Source	Capability
Component alignment	System	Component alignments are met through interface tolerances and or shim and alignment procedures. Knowledge is achieved through std practices (cubes, reference surfaces).
Provide an obstructed line of sight to all alignment cubes and reference surfaces	System	Meet by design.
SSTI and LLV1 coordinate systems	System & Launch Vehicle ICD	Comply, see drawings L305581 and 305649.
Provide an unobstructed path for thruster plume	System	Meet by design, a verification analysis will be performed, components to be considered include the solar arrays, launch vehicle adapter, and the battery radiator.
Provide spacecraft venting in accordance with the spacecraft contamination plan	System , EV-Spec	Comply, spacecraft vent's and screens are provided in the BPM top cover (TBR).
Provide access to the in-flight jumpers and battery test connector while integrated to the launch vehicle	System & Launch Vehicle	Comply, A location for the fairing door is defined to provide accessibility, see drawing 305649.
Provide accessibility to electrical test connectors	System and I&T	Meet by design, see drawing L305581.
Provide adequate interfaces and lifting points to support MGSE operations	System and I&T	Meet by design, see drawing L305581.

Alignment Requirements

- The Spacecraft shall provide the capability to align HSI, LEISA / OPA, UCB, Mag RWA , S/C RWA, Gyro's, Earth Sensors, Coarse Sun Sensors, Star Trackers, ACS Thrusters, Magnetometer, Mag Torquers, SADA, GPS Antenna's, and the GSTDN Omni Antenna's relative to the spacecraft coordinate system to the values defined within the corresponding interface control documents. The spacecraft coordinate system is defined by the optical alignment device installed on the payload platform. All pointing, knowledge and control requirements shall be expressed relative to this reference frame. Compliance will be achieved through one of the following three methods:

  1. Standard hole Tolerances at the interfaces.
  2. Tight tolerance holes with mechanical aids (alignment pin's, master tooling, etc.).
  3. Shim and alignment procedures applied during the I&T phase.

- The Spacecraft shall provide the necessary features and accessibility to achieve alignment knowledge during I&T. Alignment knowledge will be recorded utilizing standard industry practices (i.e. alignment cubes, mirrors, tooling balls, etc.).

- Alignment Stability at the spacecraft level will be determined by analysis as required.

SSTI

Alignment Requirements

Component	Requirement	Type	Capability
Hyperspectrial Imager	±0.1°	Alignment	A Master tool will be used to locate HSI on the payload platform.
LEISA Spectrometer	±TBD	Alignment	The LEISA boresight will be aligned to the OPA azimuth axis thru mech. tolerances / Analysis
Optical Pointing Assy	±TBD ±TBD	Alignment Knowledge	Meet thru mech. tolerances / Analysis OPA alignment cube fully accessible
Ultraviolet Cosmic Background Spectrometer	±1.0° ±0.1°	Alignment Knowledge	Meet thru std mech. tolerances / Analysis UCB alignment cube fully accessible
Magnetically Suspended Reaction Wheel	±2.0°	Alignment	Meet thru std mech. tolerances / Analysis
S/C Reaction Wheels	±0.25°	Alignment	Meet thru mech. tolerances / Analysis
Gyro Reference Assy	±0.5° ±0.1°	Alignment Knowledge	Meet thru std mech. tolerances / Analysis GRA alignment cubes fully accessible
Coarse Sun Sensors	±2.0°	Alignment	Meet thru std mech. tolerances / Analysis

Alignment Requirements (Cont.)

Component	Requirement	Type	Capability
Earth Sensor Assy	±0.25°	Alignment	Meet thru mech. tolerances / Analysis
	±0.1°	Knowledge	ESA alignment cube fully accessible
Star Trackers	±0.1°	Alignment	Meet thru mech. tolerances / Analysis
	±0.01°	Knowledge	Star tracker alignment reference surfaces accessible with light shade and MLI removed
ACS Thrusters	±0.5° primary	Alignment	Meet thru shim and alignment procedures
	±1.5° redundant	Alignment	Meet thru mech. tolerances / Analysis
Magnetometer	±1.0°	Alignment	Meet thru std mech. tolerances / Analysis
Magnetic Torquers	±2.0°	Alignment	Meet thru std mech. tolerances / Analysis
Solar Array Drive Assy	±1.0° axial	Alignment	Meet thru mech. tolerances / Analysis
	±0.5° rotation	knowledge	Meet thru mech. tolerances / Analysis
In-plane GPS Antenna's	±.25 inches	Alignment	Coplanarity meet thru mech. tolerances / Analys.
	TBD inches	Stability	Verified by analysis as required
GSTDN Antenna's Nadir & Zenith pointing	±2.5° (TBR)	Alignment	Meet thru mech. tolerances / Analysis

Spacecraft Configuration

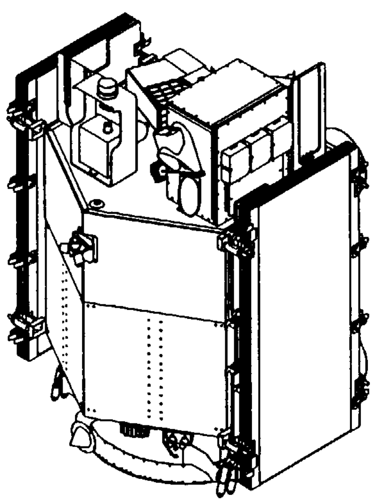
- Basic configuration / layout is based on the TRW AB600 spacecraft bus, key features include:
    - light weight composite structure
    - modular compartments for batteries, an integral propulsion system, bus equipment, payload support equipment / tech demo's, and payloads.

- Primary payloads (HSI, UCB, LEISA) mount to the upper payload platform.

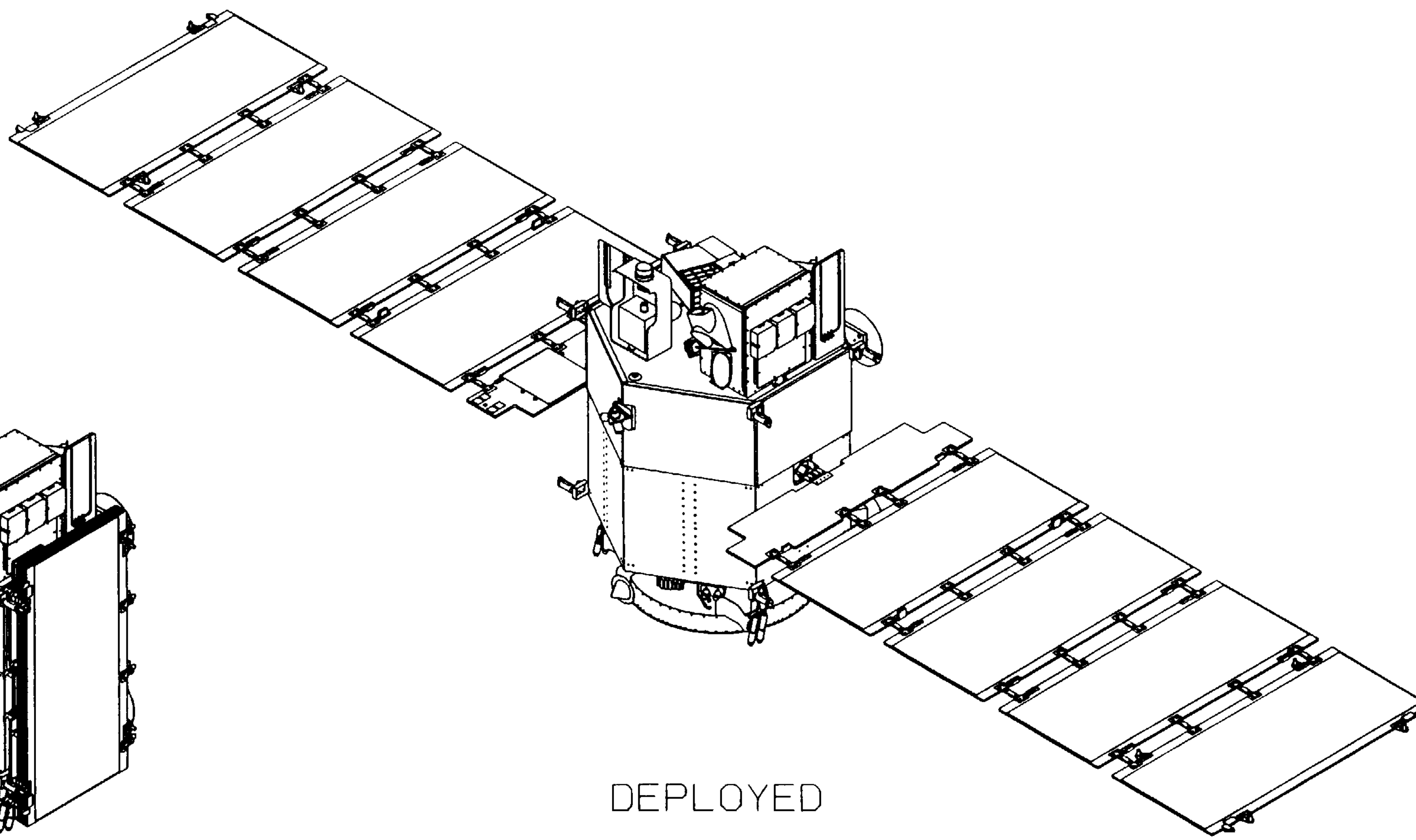
- The Solar Array architecture includes a dual wing flat pack (stowed) array with four panels per side dedicated for the bus cells and a solid panel yoke which accommodates the solar cell experiments. Deployment occurs in an accordion fashion by way of G&H Technology non-explosive release devices and strain energy hinges.

- Spacecraft will utilize LMSC LLV-based launch services, and is capable of being stowed / integrated within an LLV1 92" fairing.

Spacecraft Configuration



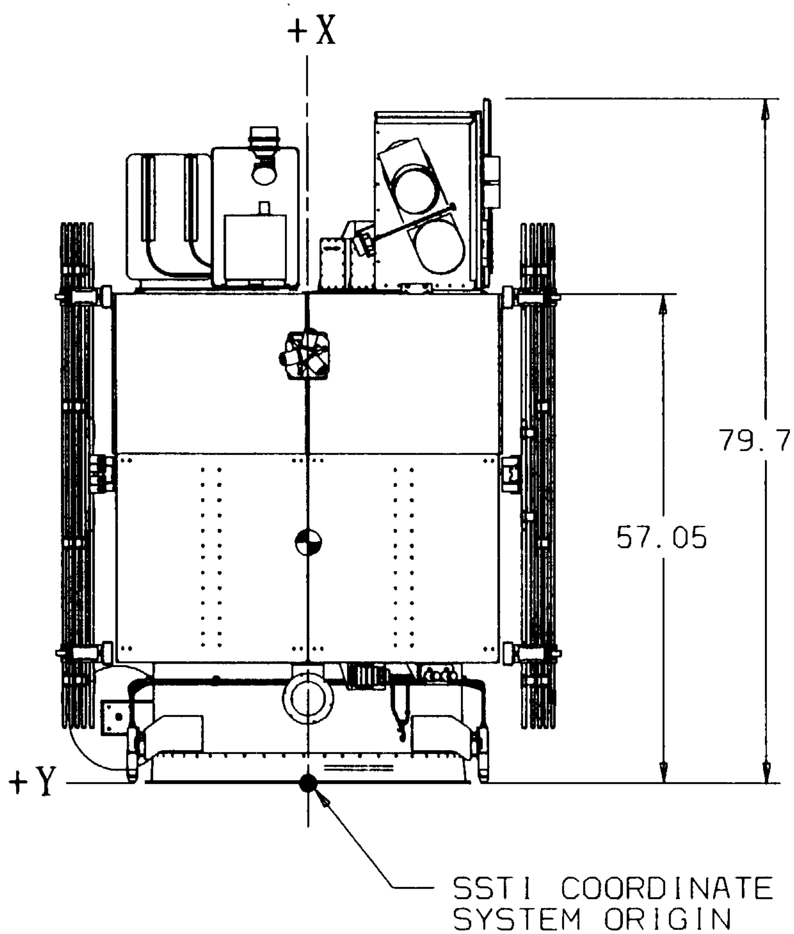
STOWED



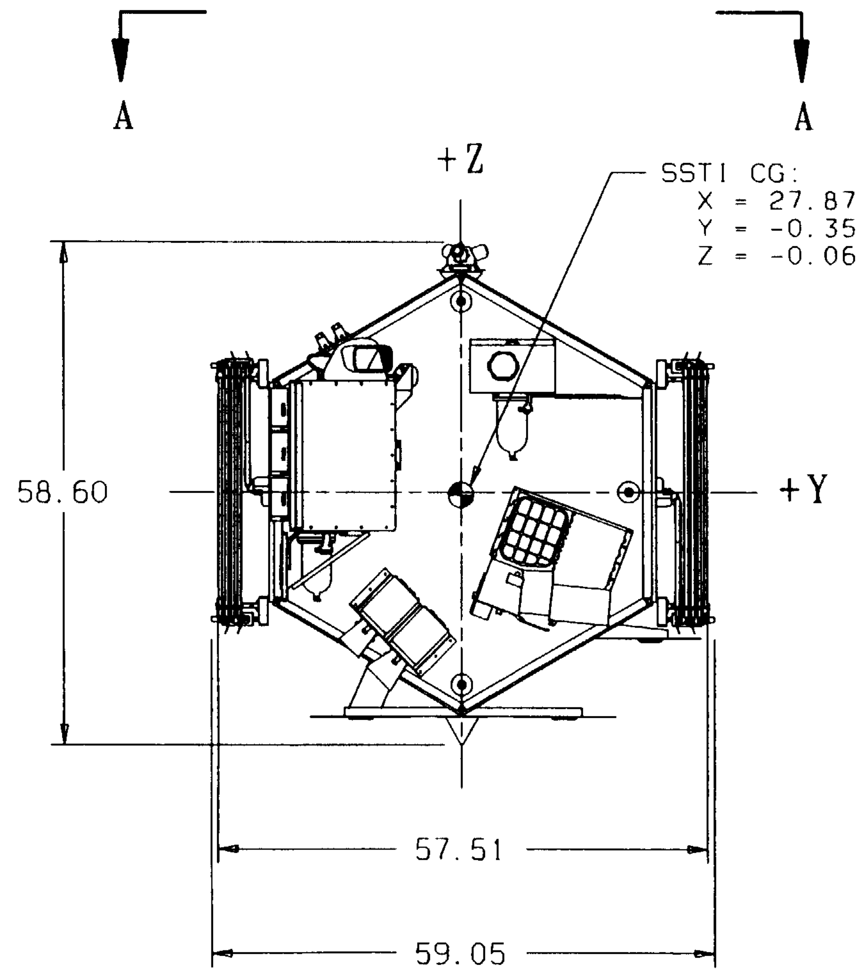
DEPLOYED

Stowed Configuration

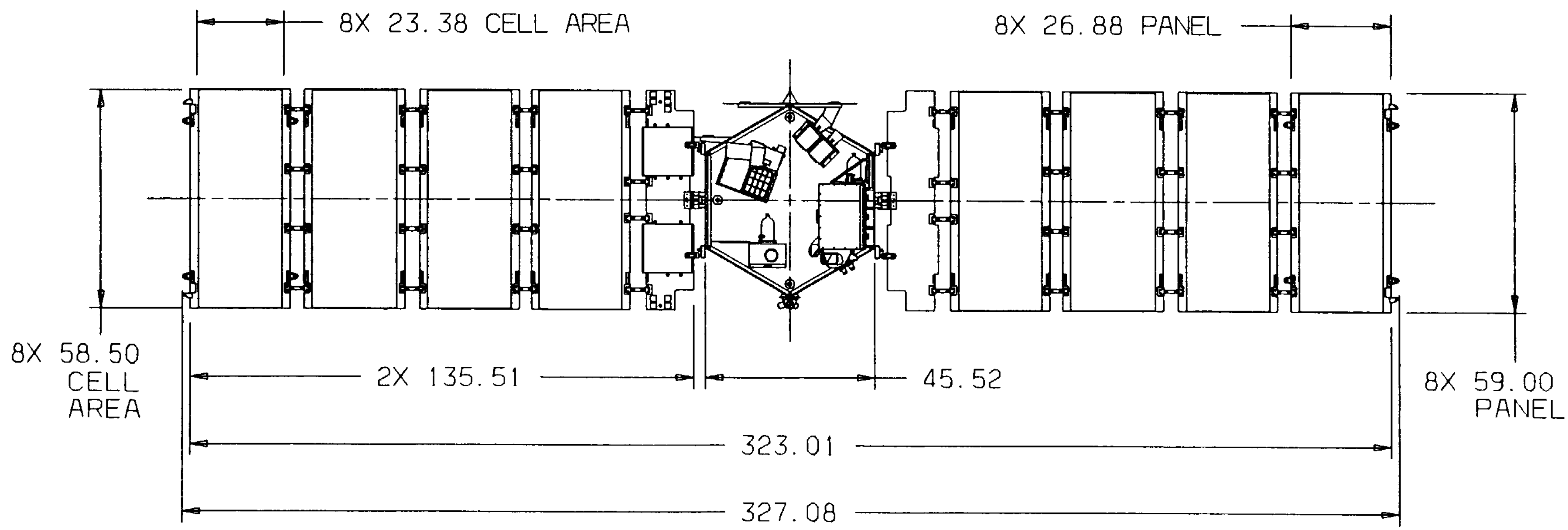
Basic Dimensions, Coordinate System, C.G.



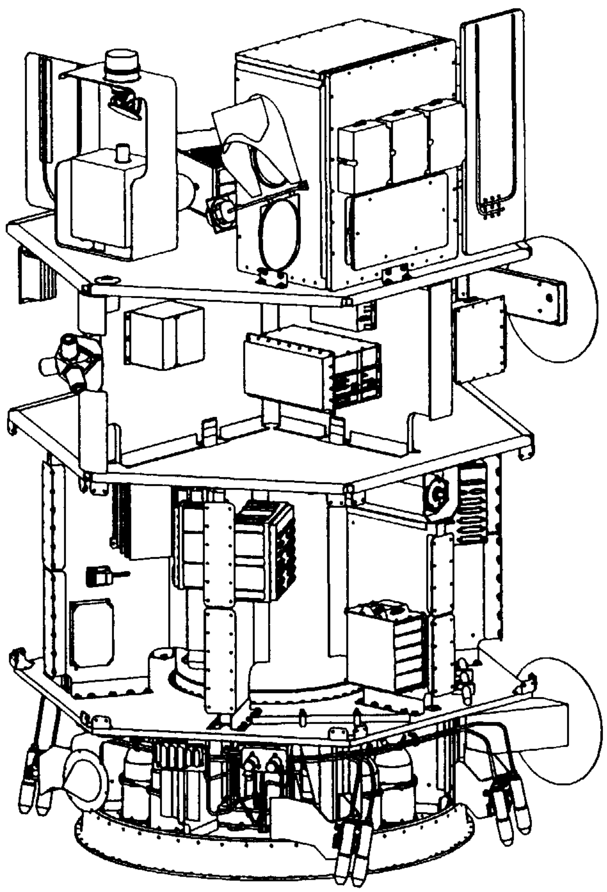
VIEW A-A
(ROTATED 180°)



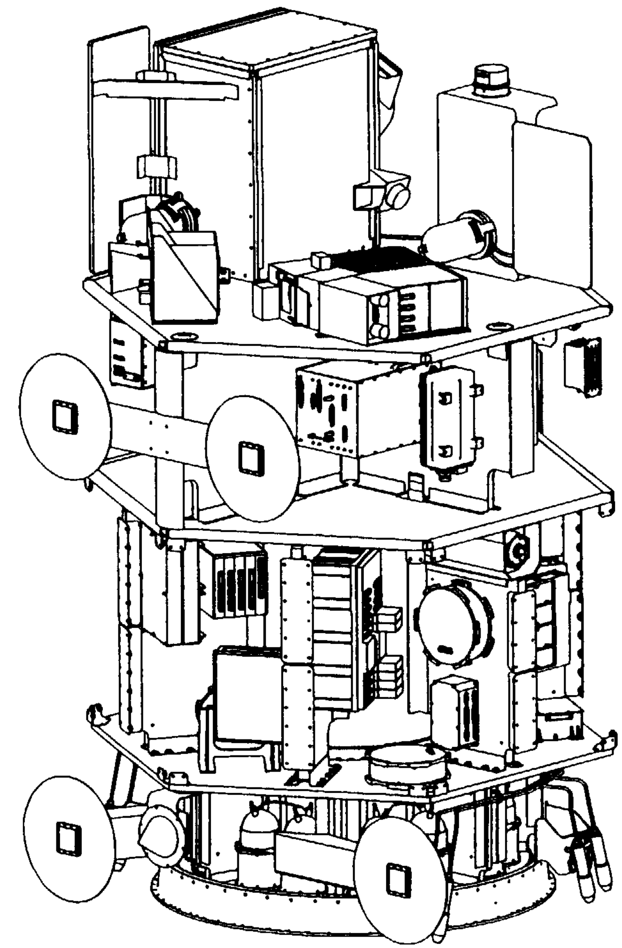
Deployed Configuration
Basic Dimensions



Spacecraft Configuration



NADIR ISO



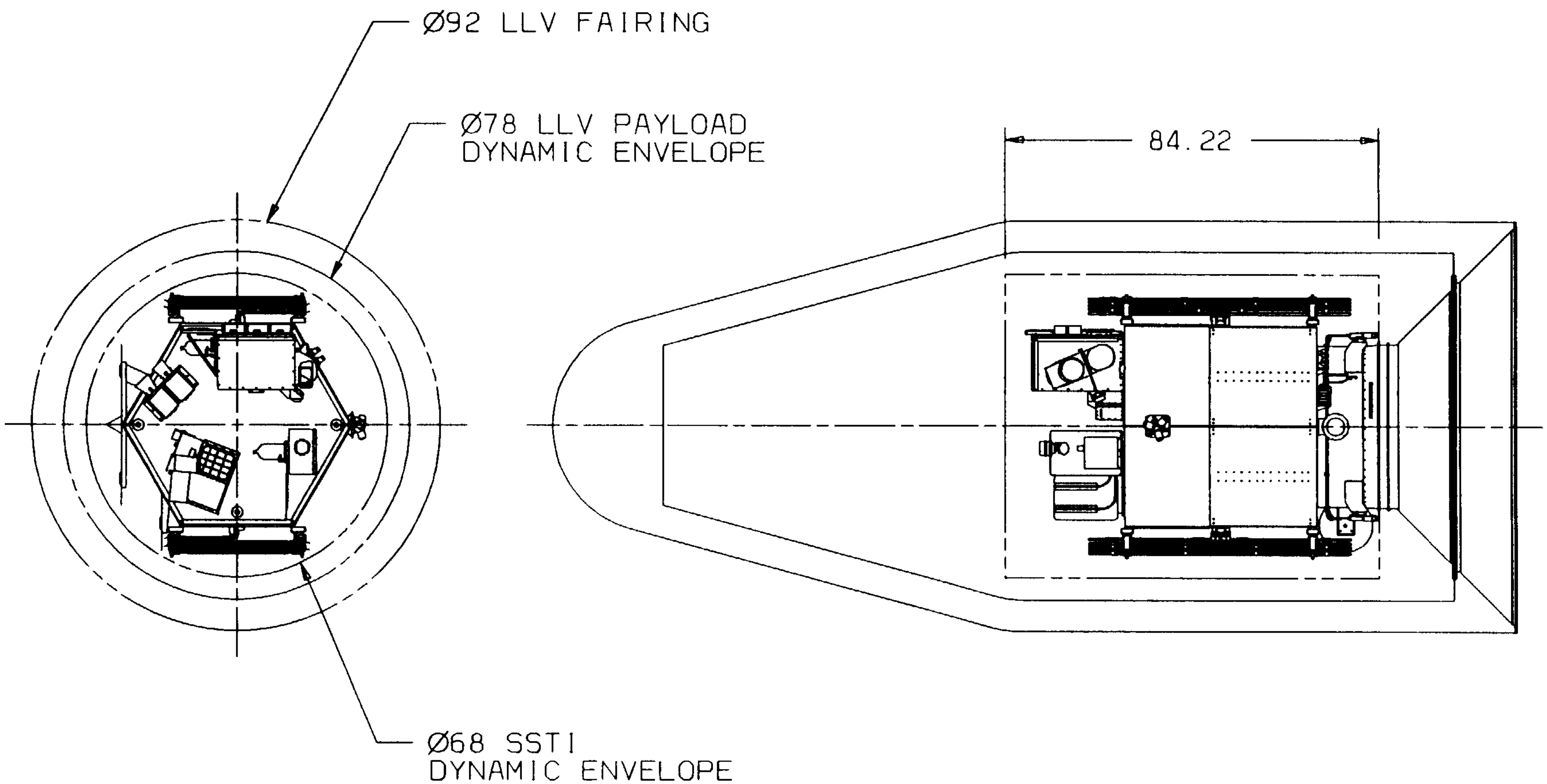
ZENITH ISO

SSTI

Launch Vehicle Interfaces

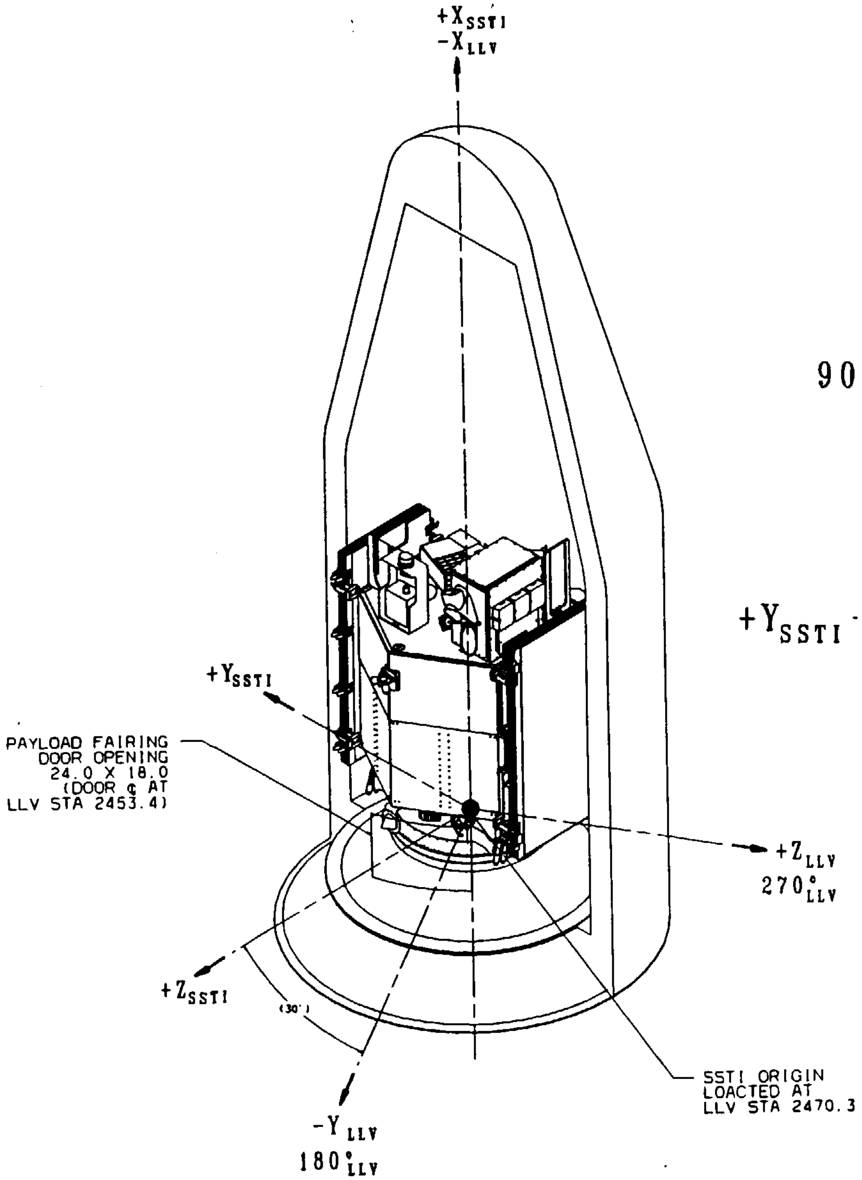
- The SSTI configuration is compatible with the LMSC LLV1 92" fairing.
- Ø 68.0 x 84.22 inch dynamic envelope.
- Ø 66.0 x 83.22 inch static envelope.
- A 24.0 x 18.0 inch fairing door allows access to the propulsion fill and drain valves, in-flight jumpers (IFJ's), and the battery test connector.
- The SSTI / LLV mechanical interface occurs at the LMSC provided 38 inch separable adapter, key features include:
    - mounting flange with 60 No. 10-32 fasteners on a Ø37.15 inch bolt circle (master tool / drill template provided by TRW).
    - marmon clamp separation system
    - two electrical separation connectors located 180° apart

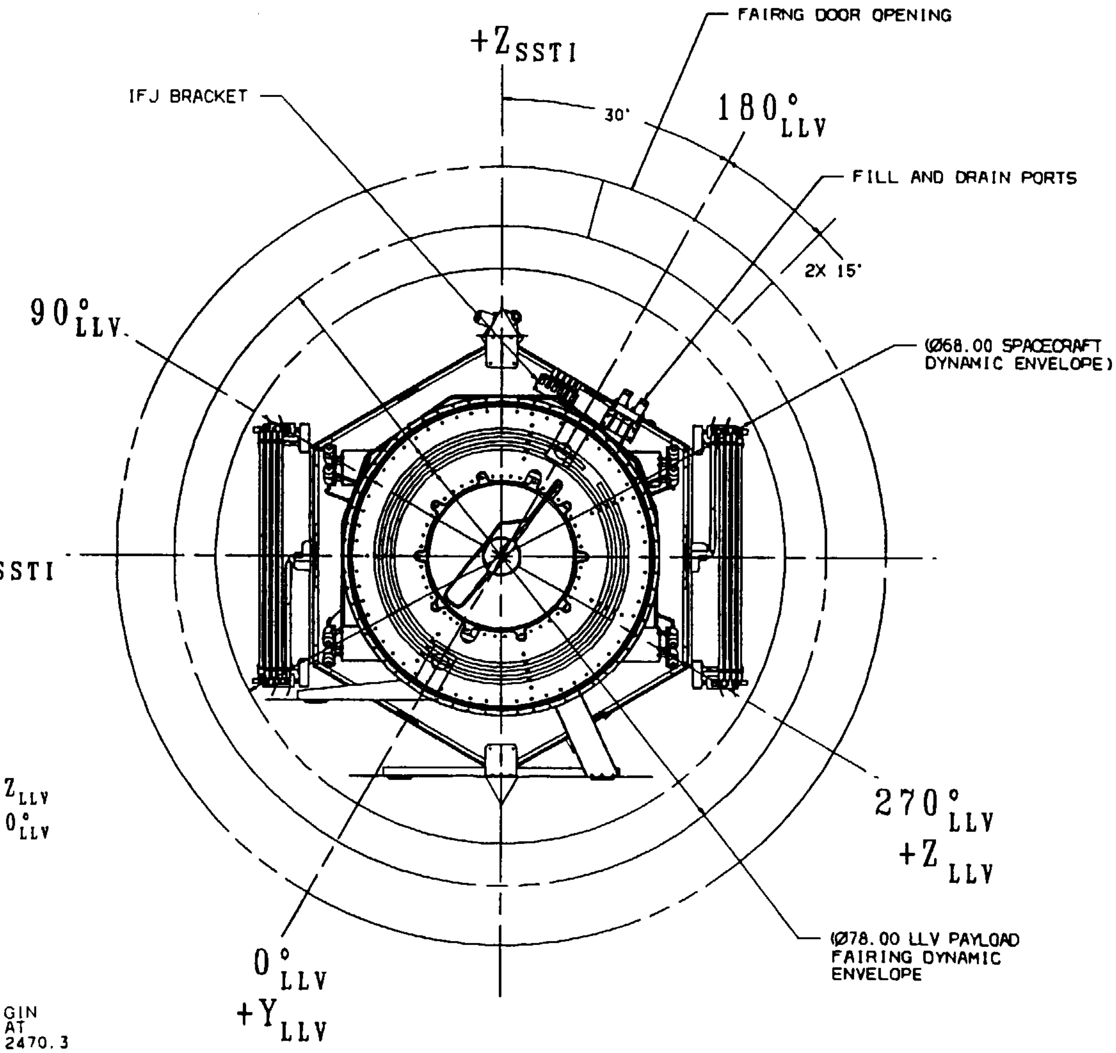
Spacecraft in LLV1 Fairing



Launch Vehicle Interfaces

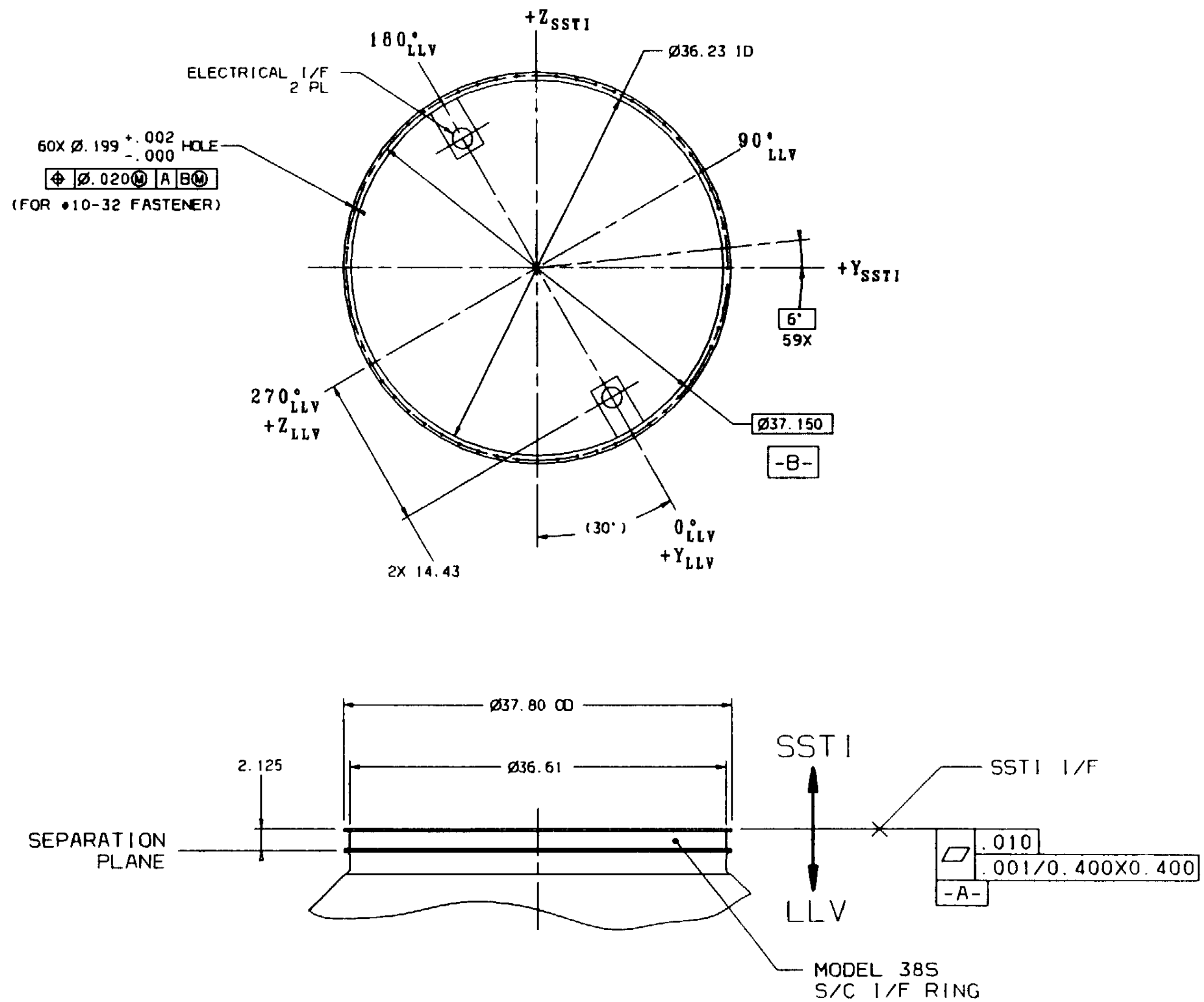
LLV / SSTI Coordinate System, Door location & Accessibility



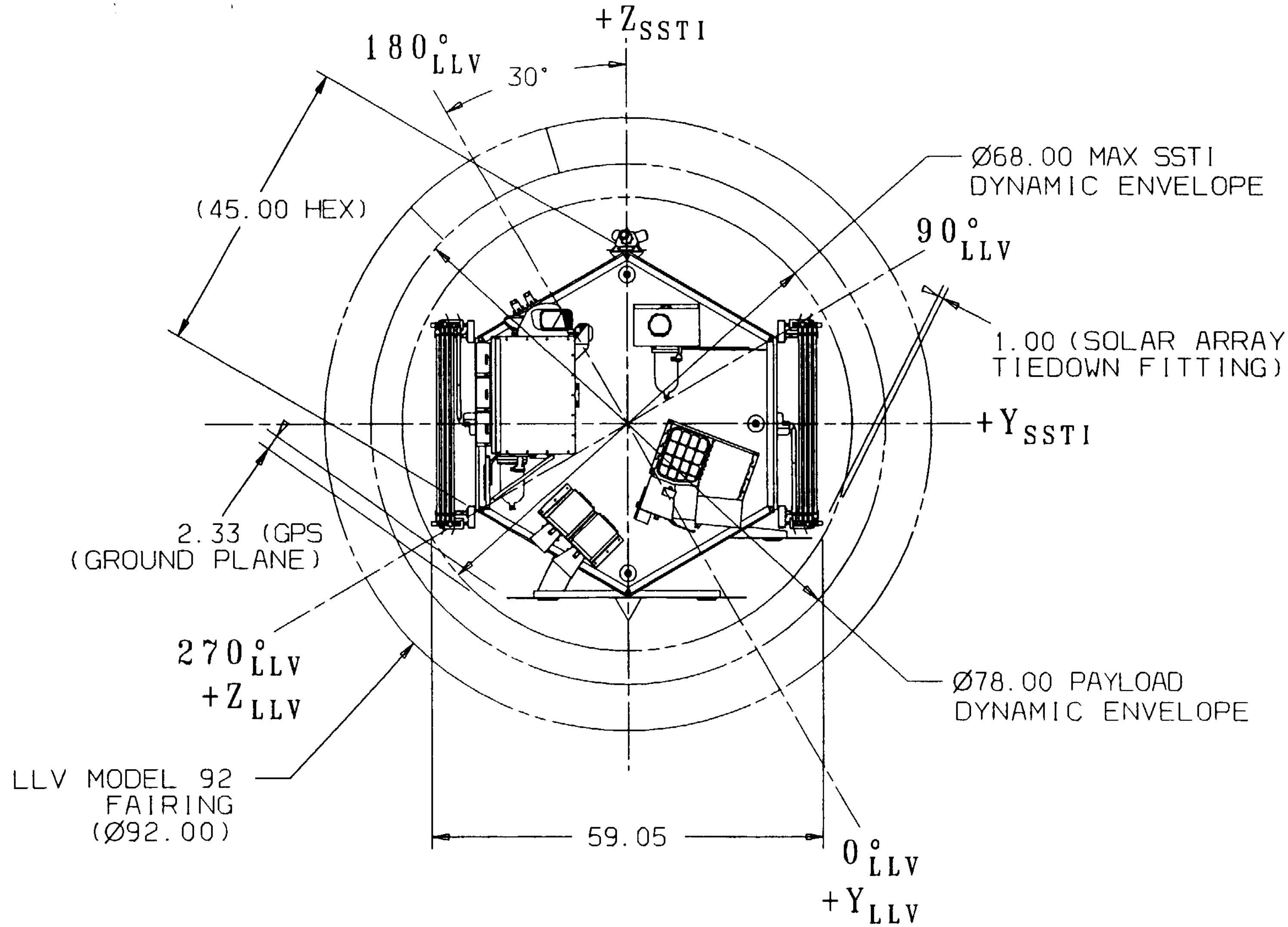


Launch Vehicle Interfaces

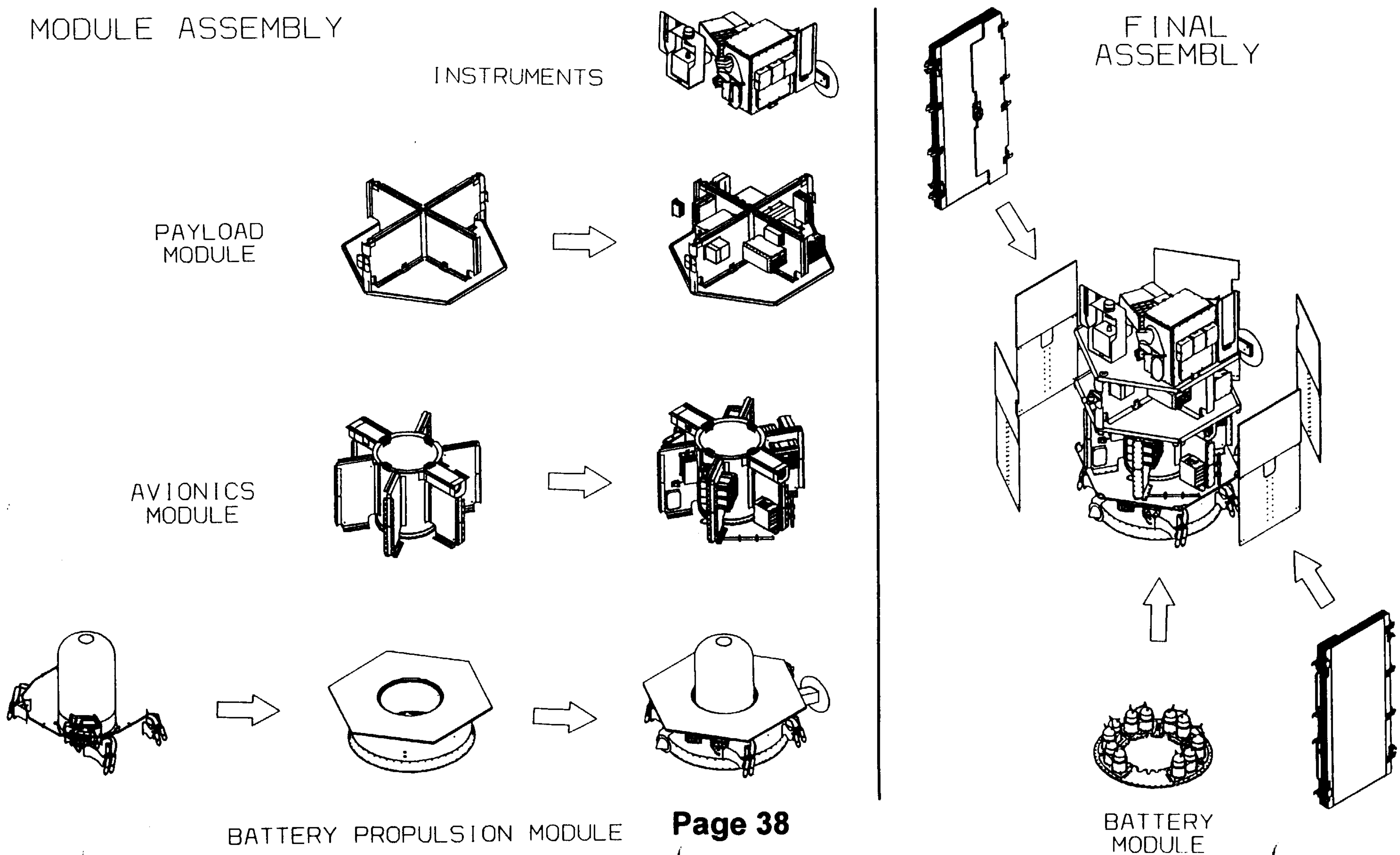
Lockheed Model 38S Adapter Mechanical / Electrical Definition



Spacecraft / LLV1 Clearances



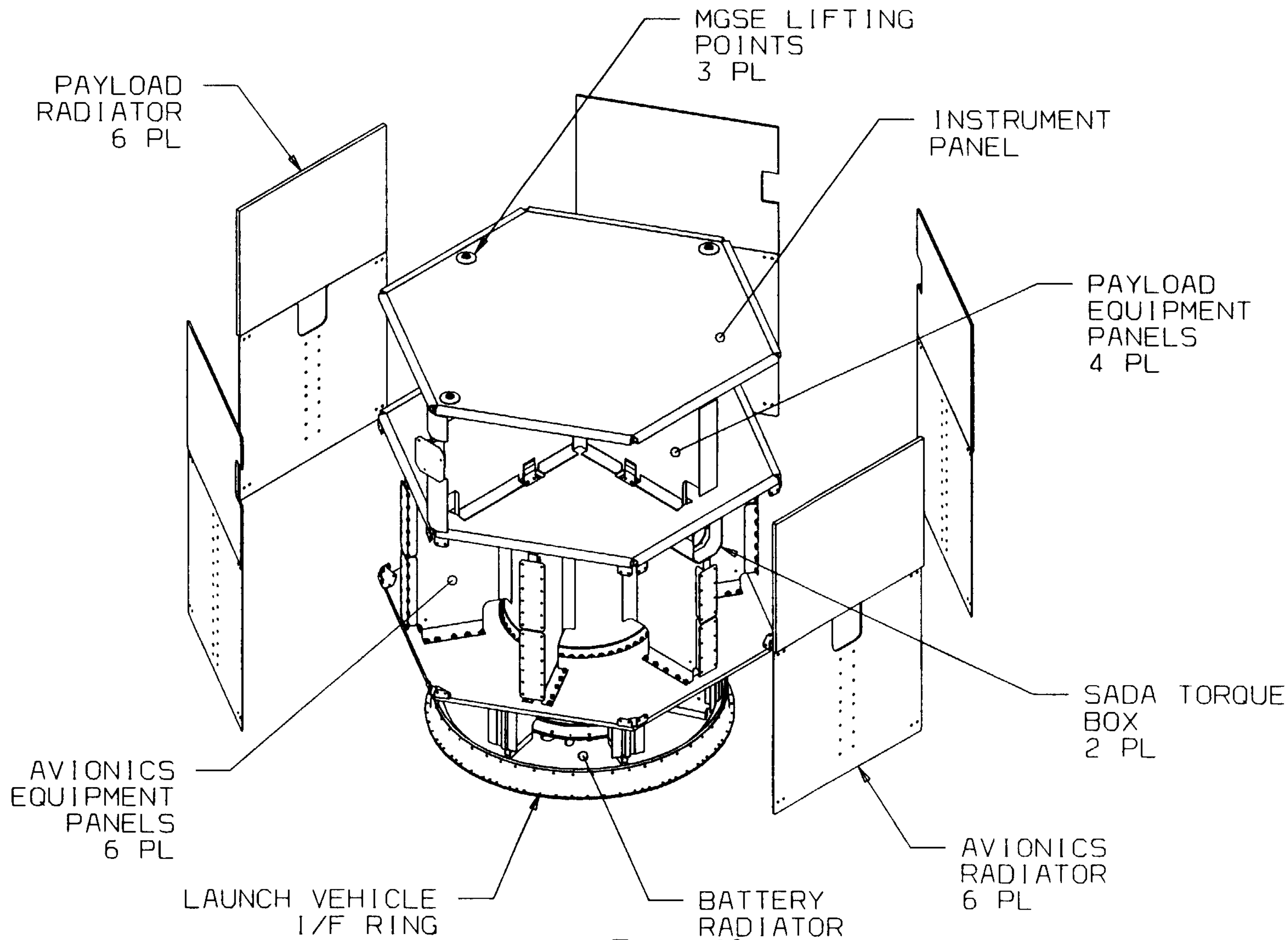
Spacecraft Modularity



Structure Interfaces

- The SSTI structure is a modular composite / polycynate design based on the TRW AB600 spacecraft bus.
- The Battery / Propulsion module consists of half of the central cylinder (which supports the propulsion tank) and an outer cylinder attached by 7 shear webs. A lower close-out panel serves as the mounting surface and radiator for the battery's. The top cover supports the lower solar array attachment points and additional equipment.
- The Avionics module consists of the second half of the central cylinder, 6 radial shear webs, 6 removable radiator panels, and 2 torque boxes which house the solar array drive assembly. Equipment is mounted to the shear webs which also act as a thermal path to the radiators.
- The payload module consists of an upper and lower platform joined together with 3 equipment panels in a cruciform configuration. Payload instruments are mounted to the outboard surface of the upper platform.
- Ground Planes: all equipment mounting surfaces will be covered with 3 mil's of aluminum for secondary power and electrostatic discharge protection. Module to module continuity will be provided through ground straps.

Primary Structure



Battery/Propulsion Module (BPM)

interface features

- The battery module consists of 6 NiH battery packs (two 23 Ah dual cell common pressure vessels per pack) mounted to a dedicated aft facing battery radiator with an exterior dual circular heat pipe.

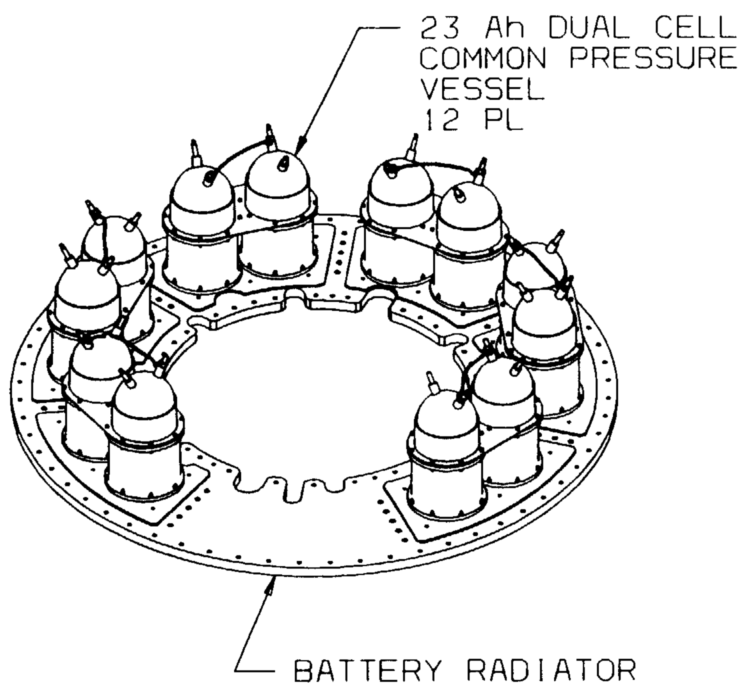
- The propulsion module consists of a single propulsion tank which mounts to a metallic ring on the end of the central cylinder, 4 MRE-1 dual thruster modules supported by brackets off the BPM outer cylinder, the propulsion distribution module housed within one of the 7 BPM bays, and associated propellant lines routed on the exterior of the outer cylinder.

- The BPM top cover supports 2 GSTDN (S-Band) Antennas, electrical in-flight jumpers and test connectors, and the propellant fill and drain valves.

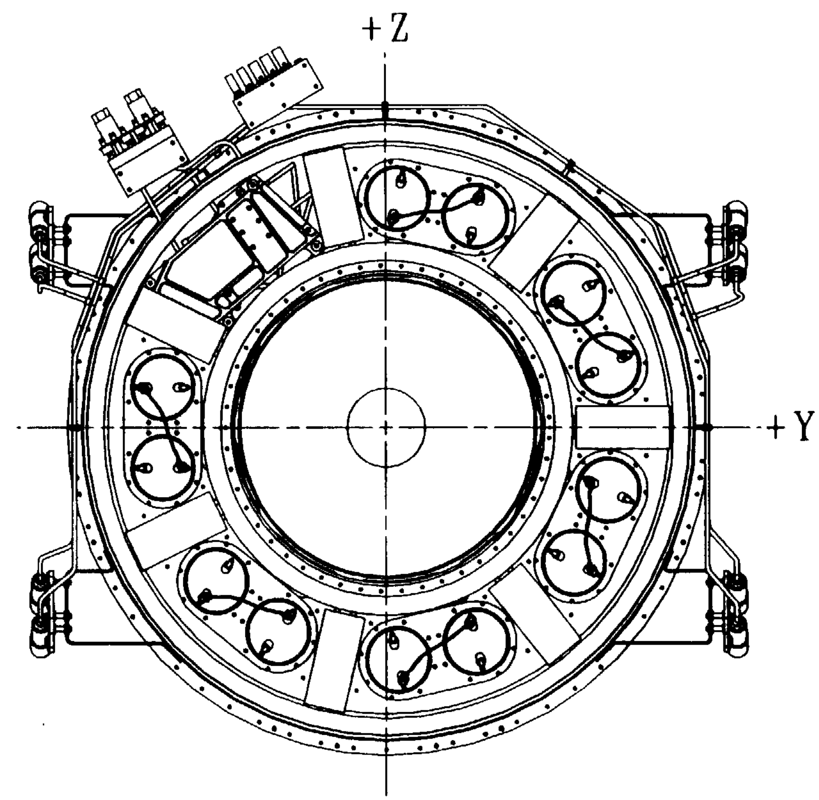
- The BPM outer cylinder supports 2 GPS Antennas.

- The Battery Module must be integrated with the LMSC LLV separable adapter removed

Battery Module Layout

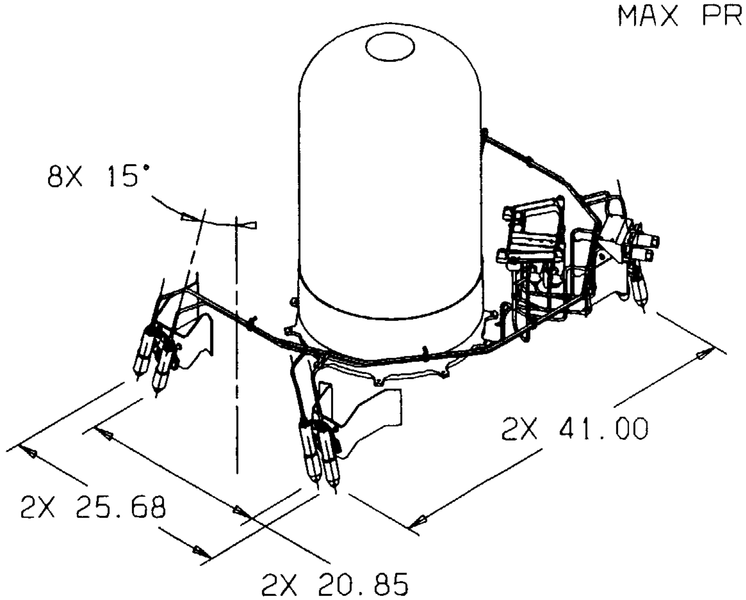


BATTERY MODULE ISO

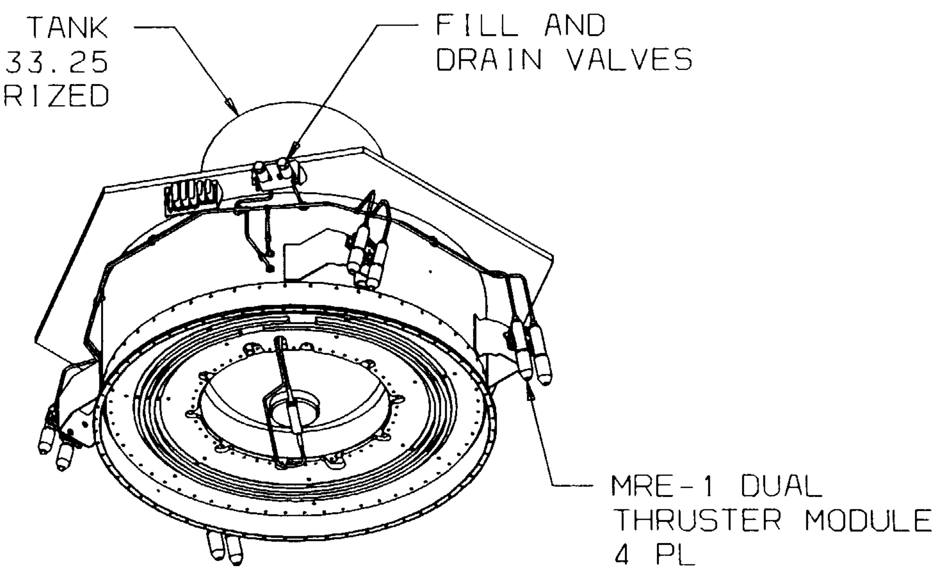


INTEGRATED BATTERY
MODULE PLAN VIEW

Propulsion Module Layout



PROPULSION MODULE ISO



INTEGRATED PROPULSION
MODULE AFT ISO

Avionics Module Interfaces

- The Avionics Module accommodates the following bus equipment:

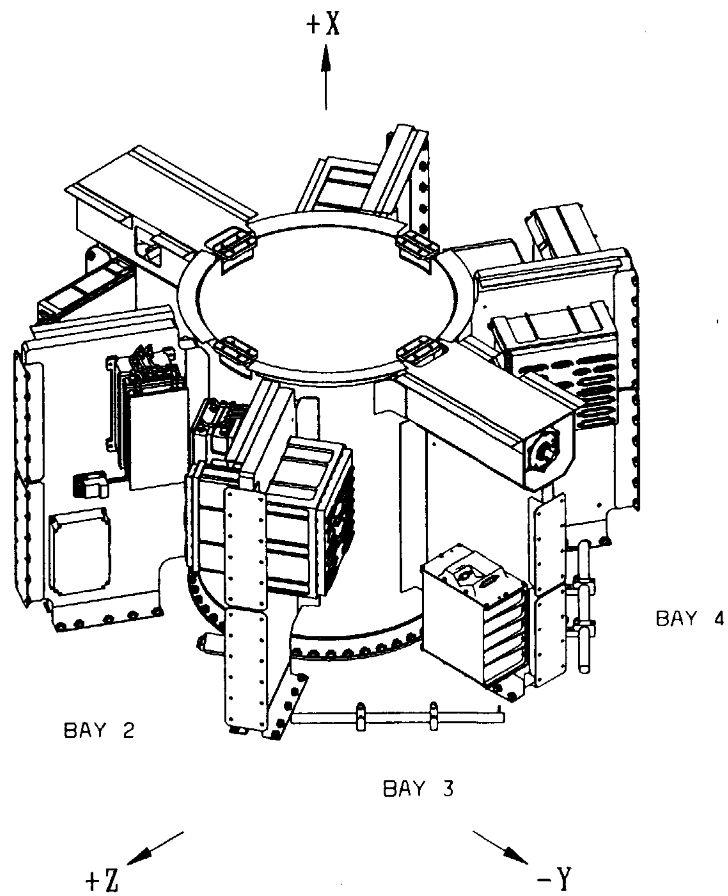
  - Reaction Wheels (4)
  - Gyro (3)
  - Magnetic Torquer (3)
  - Magnetometer Sensor and Elect.
  - Control Electronics
  - Valve Drive Elect.
  - Solar Array Drive Assy (2)
  - SADA Drive Elect.
  - Solar Array Regulator (2)
  - Power Control Unit
  - Deployment Device Controller
  - Spacecraft Computer (2)
  - Data I/F Unit (2)
  - GSTDN Transponder (2)
  - RF Assembly

- Removable radiators allow access to bus bays / equipment.

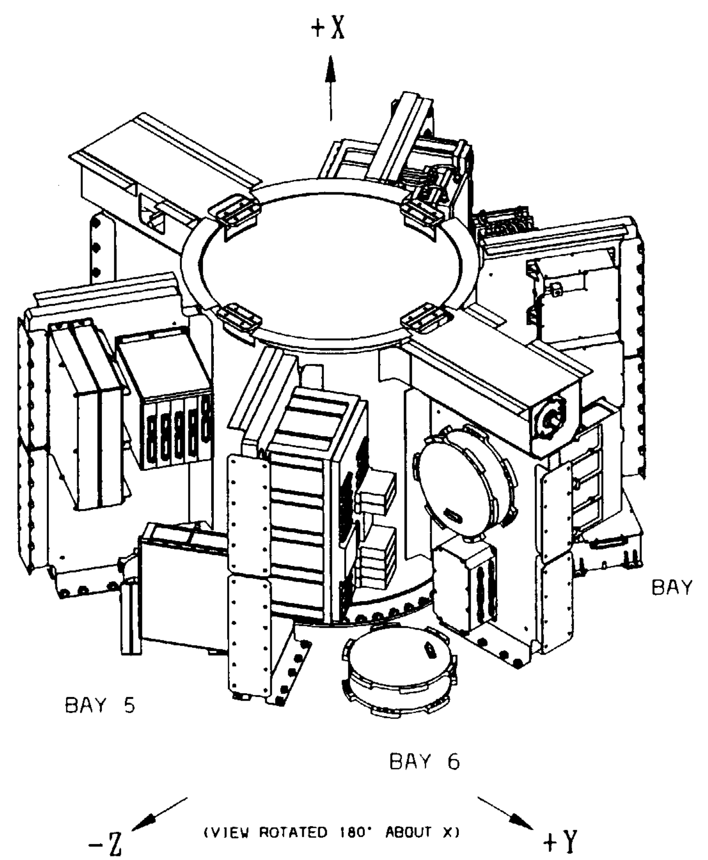
- Equipment is attached to shear webs and the BPM top cover via embedded inserts.

- Dimpled aluminum foil is used between the equipment and panels to achieve thermal and electrical continuity.

Avionics Module Layout
Isometric Views



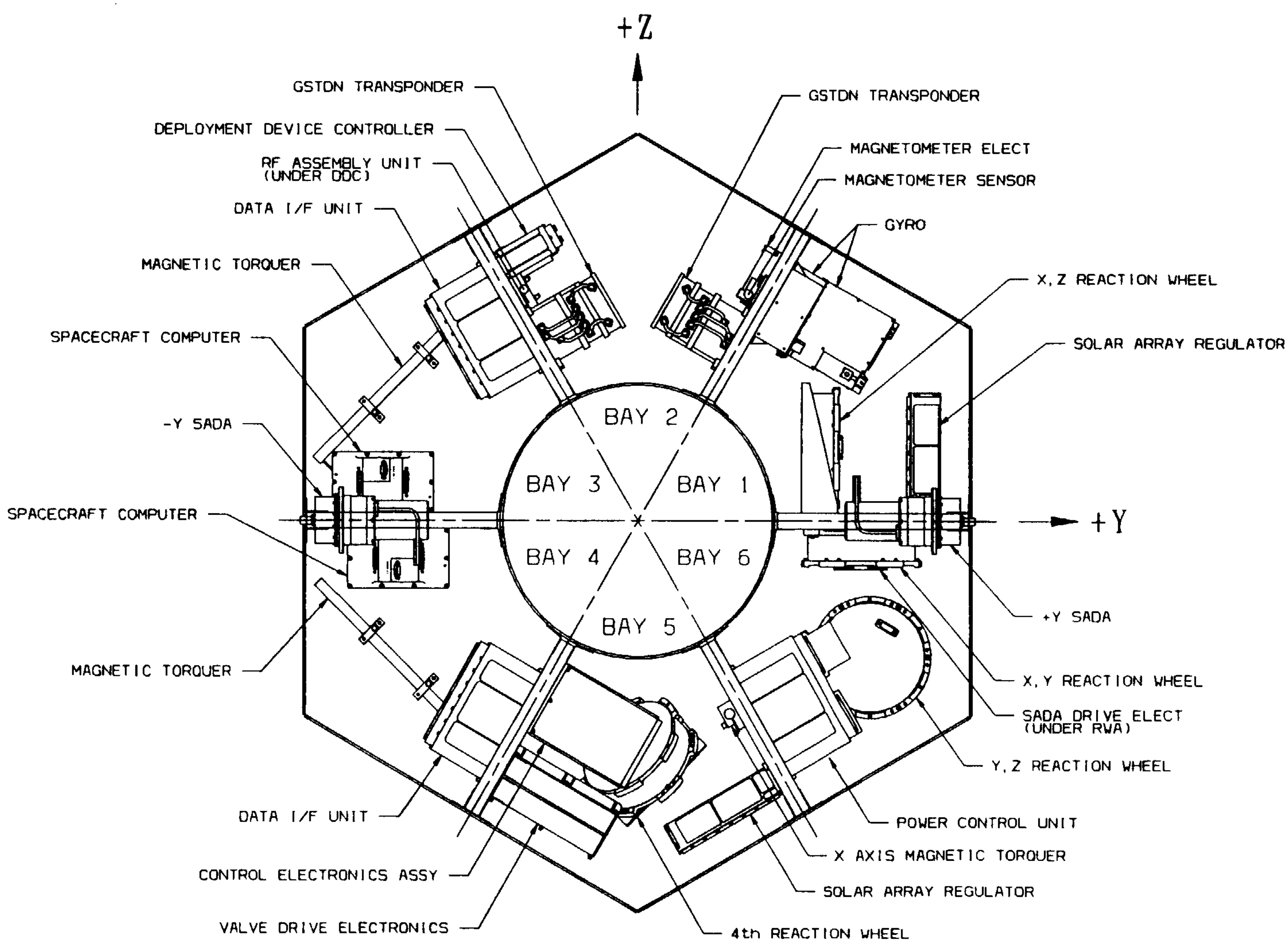
NADIR FACE



ZENITH FACE

Avionics Module Layout

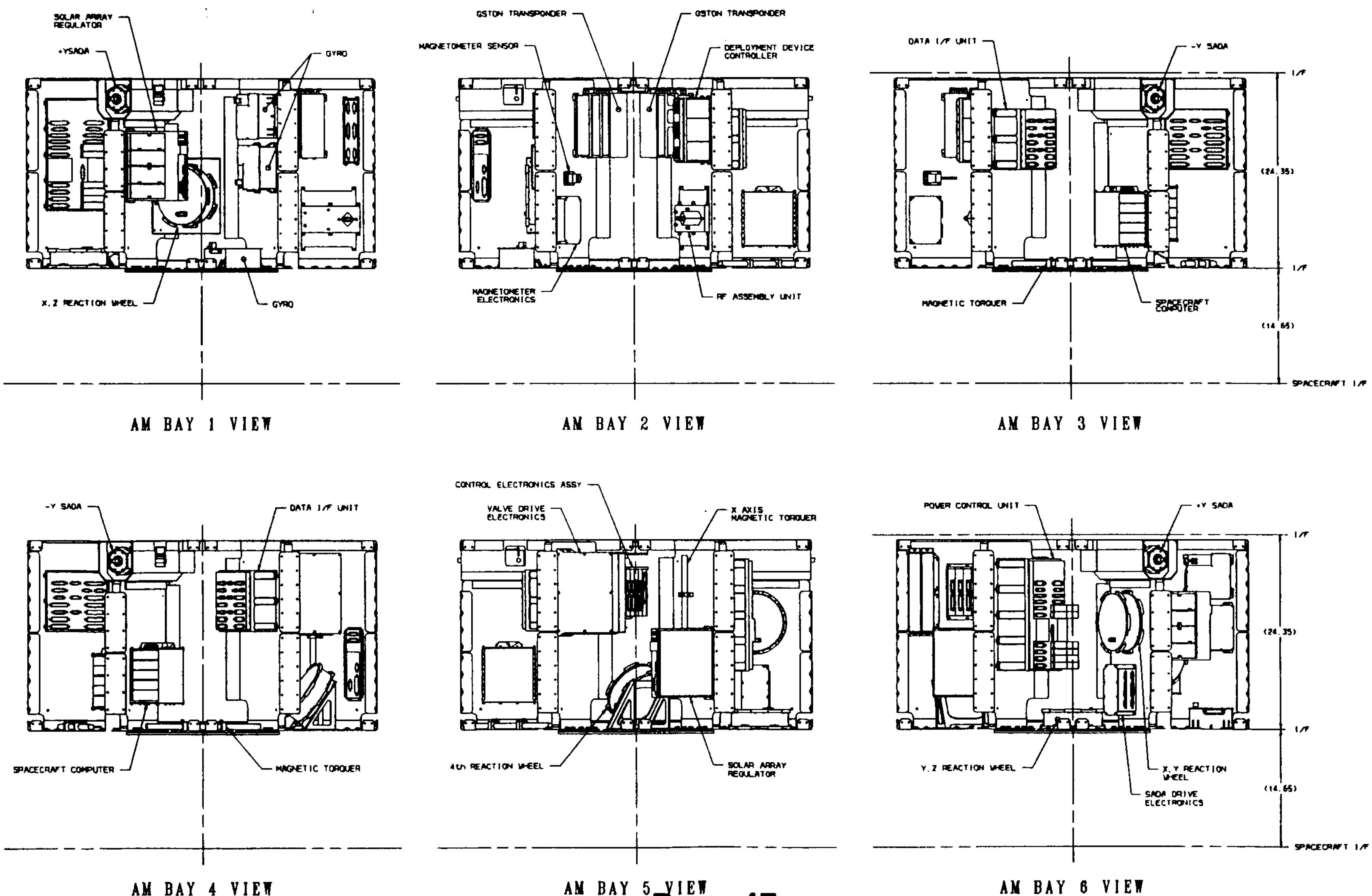
Plan View



VIEW LOOKING -X

Avionics Module Layout

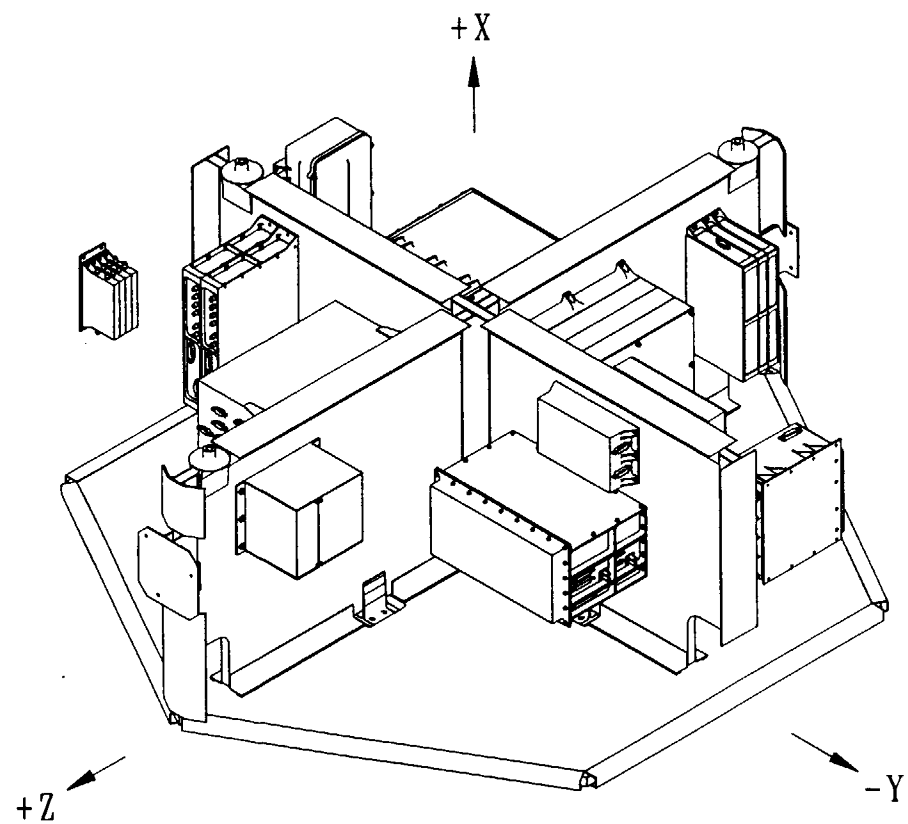
Bay Views



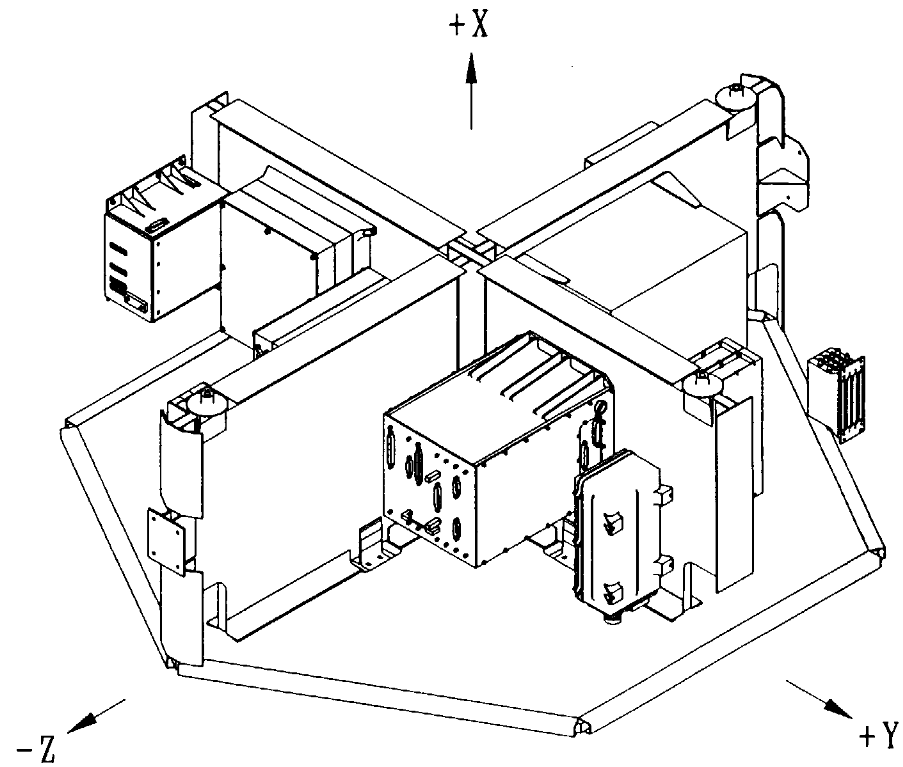
Payload Module Interfaces

- The Payload Module accommodates the following payload support equipment and technology demonstrations:
  - Payload Elect. Assy
  - Solid State Recorder
  - HSI Control Elect.
  - HSI Converter Elect.
  - UCB Elect.
  - Goddard Elect. Module
  - Mag Reaction Wheel
  - Gas Proportional Counter
  - GPS Quad Preamp
  - GPS Receiver
  - Photovoltaic Regulator Kit Experiment
  - Advanced Packaging Experiment
- Additionally the Payload Module supports the Earth Horizon Sensor Module, upper GPS Antenna's, Cascade Solar Cell Experiment, and the Metal Matrix Heat Strap.
- Removable radiators allow access to payload support equipment and tech demo's.
- Equipment is attached to the equipment panels and $\pm$Y radiators via embedded inserts.
- Dimpled aluminum foil is used between the equipment and panels to achieve thermal and electrical continuity.

Payload Module Layout
Isometric Views



NADIR FACE

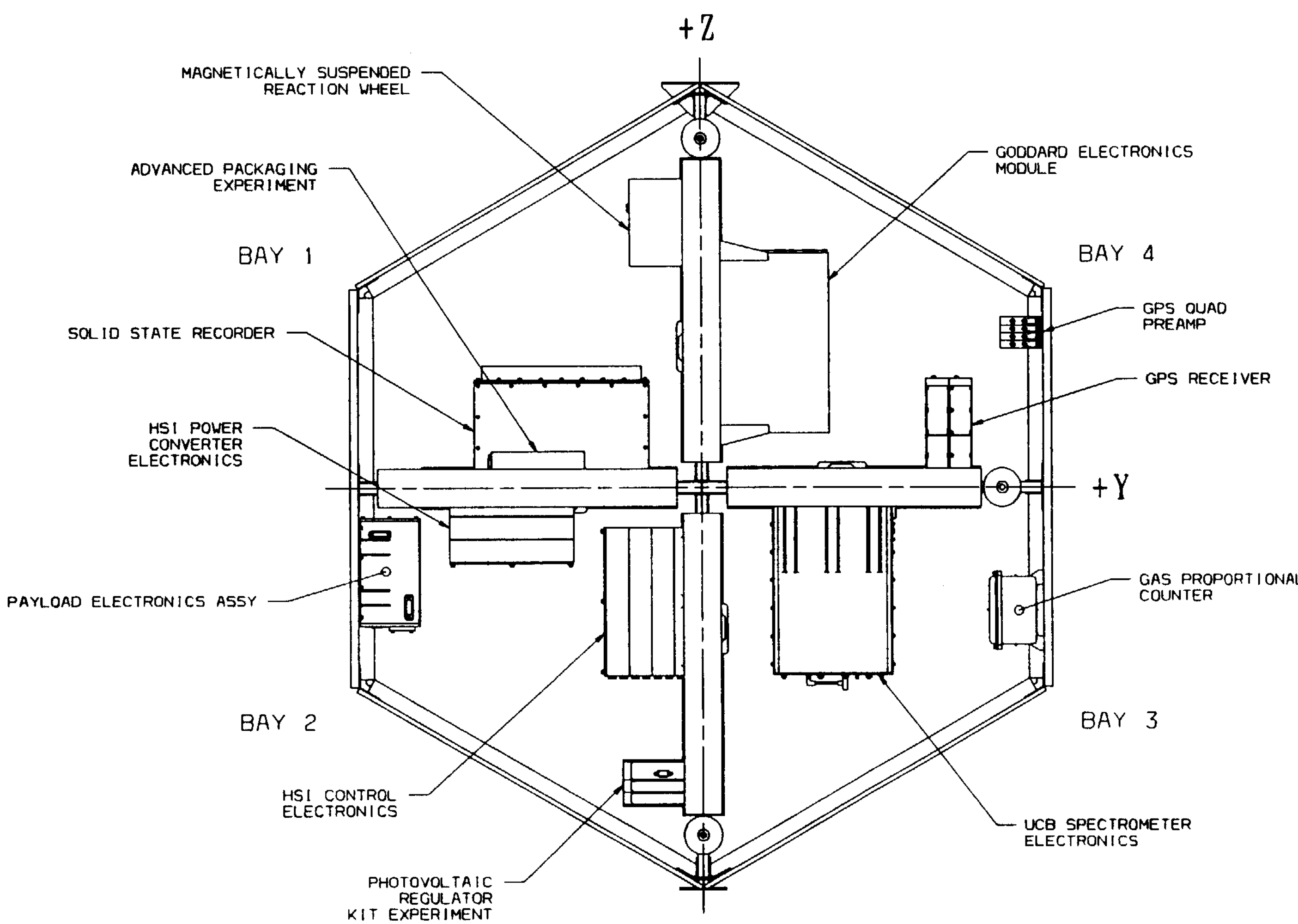


(VIEW ROTATED 180° ABOUT X)

ZENITH FACE

Payload Module Layout

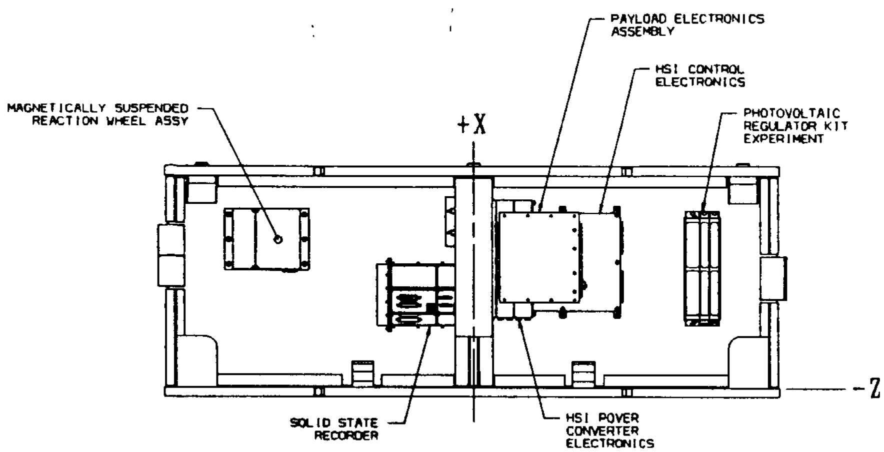
Plan View



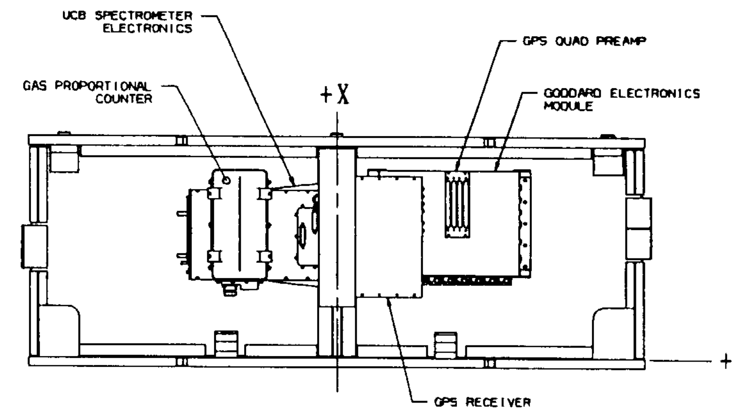
VIEW LOOKING -X
(INSTRUMENT PANEL REMOVED FOR CLARITY)

Payload Module Layout

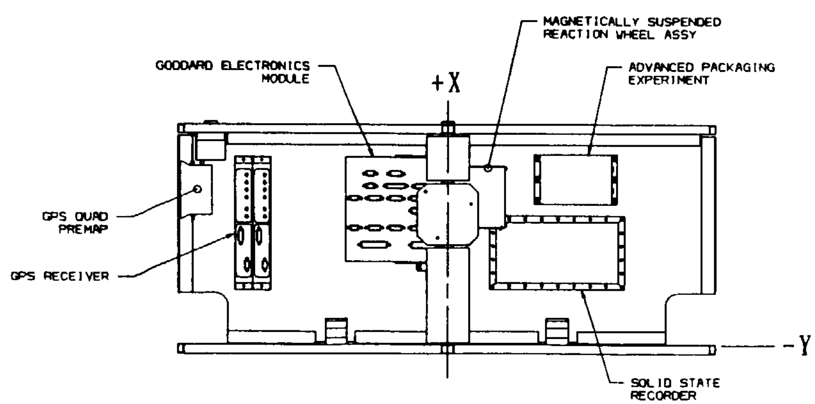
Bay Views



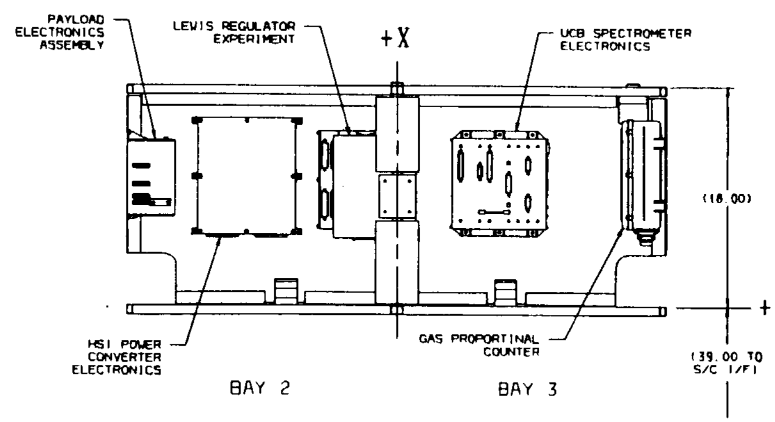
VIEW E-E
VIEW ROTATED 90° CCW
(RADIATOR PANELS REMOVED FOR CLARITY)



VIEW F-F
VIEW ROTATED 90° CW
(RADIATOR PANELS REMOVED FOR CLARITY)



VIEW G-G
(RADIATORS REMOVED FOR CLARITY)



VIEW H-H
VIEW ROTATED 180°
(RADIATORS REMOVED FOR CLARITY)

SSTI

Payload Instrument Interfaces

TRW

- The Payload Platform accommodates the following:

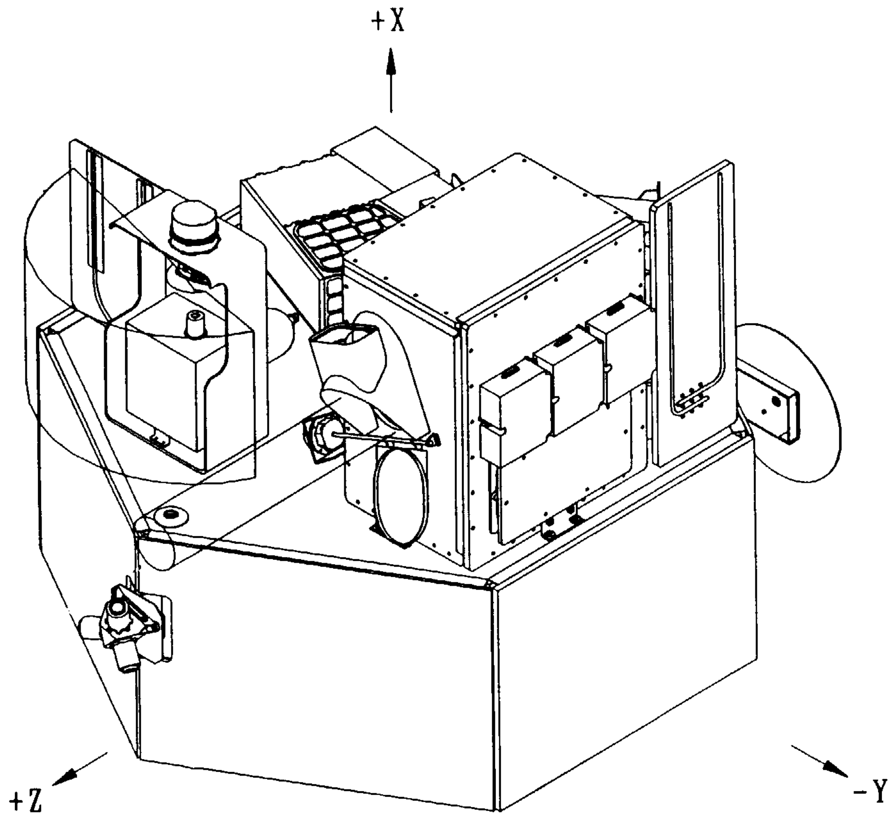
- Hyper Spectral Imager (HSI)	(primary payload)
- Linear Etalon Imaging Spectral Array (LEISA)	(primary Payload)
> Optical Pointing Assembly	
> Cryocooler	
- Ultraviolet Cosmic Background Spectrograph	(primary payload)
- Narrow Field of View Star Tracker	(core bus equipment)
- Wide Field of View Star Tracker	(technology demonstration)

- HSI and LEISA are attached to the payload platform via flexures to provide thermal and structural isolation.

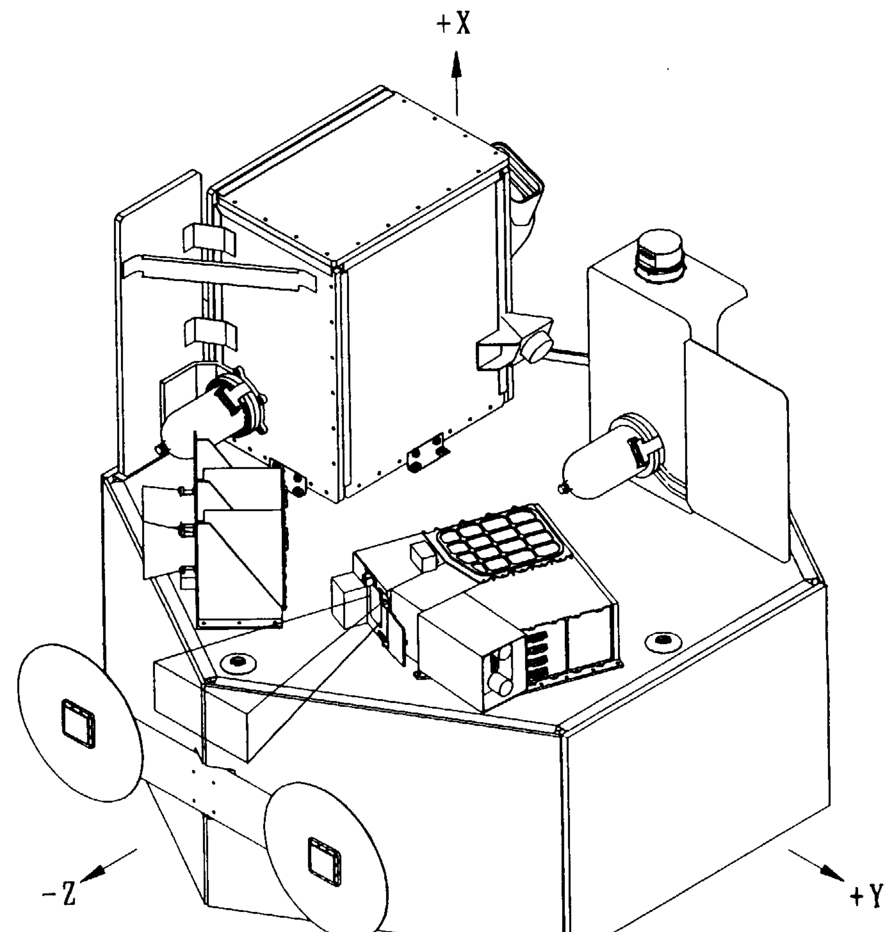
- The UCB Spectrograph and Star Tracker's are thermally isolated from the payload platform via fiberglass standoffs.

- Each payload instrument has a dedicated radiator, LEISA and the two cryocoolers (HSI & LEISA) interface with their respective radiators via heat pipes

Payload Instrument Layout
Isometric Views



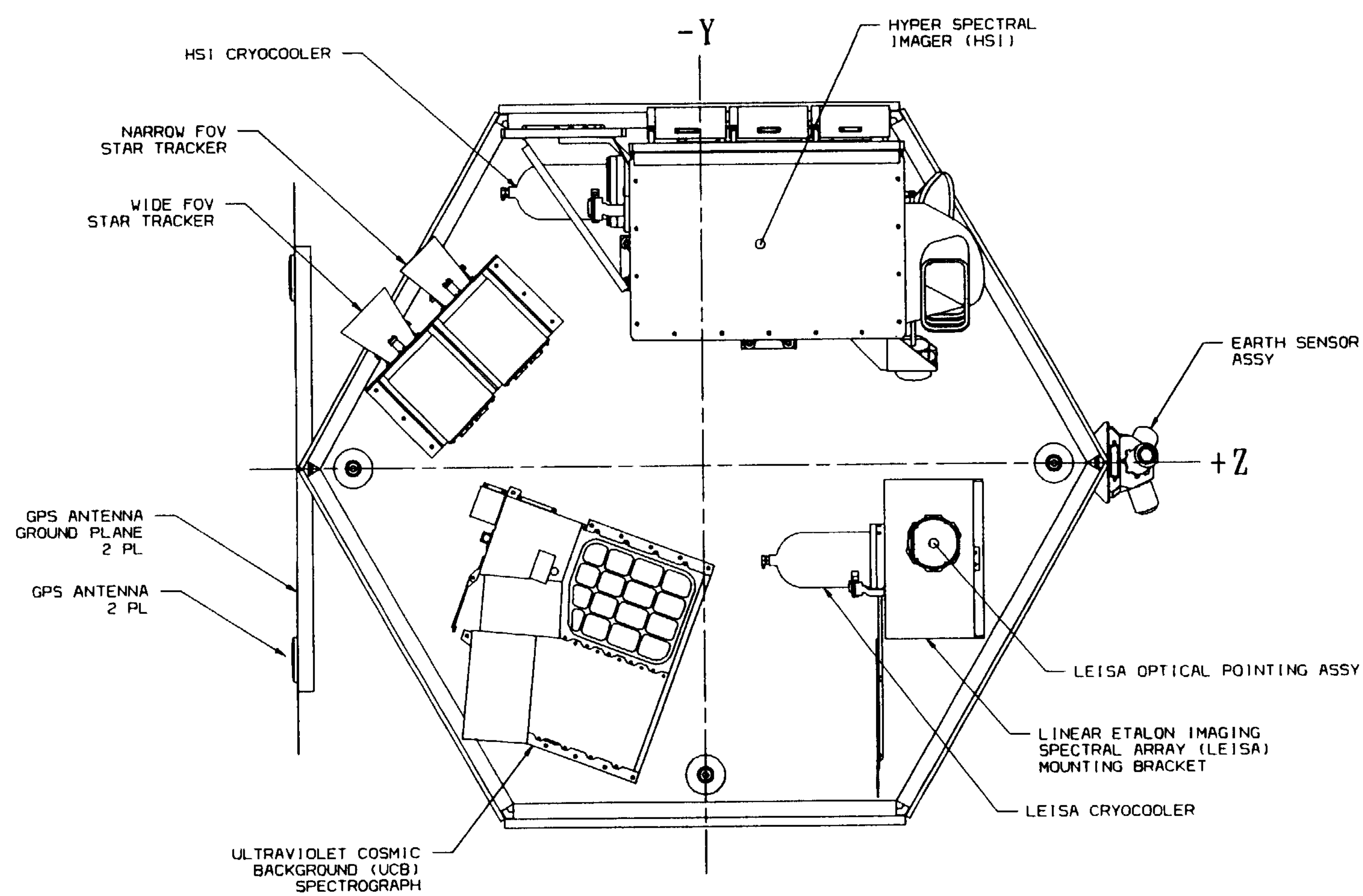
NADIR FACE



ZENITH FACE

Payload Instrument Layout

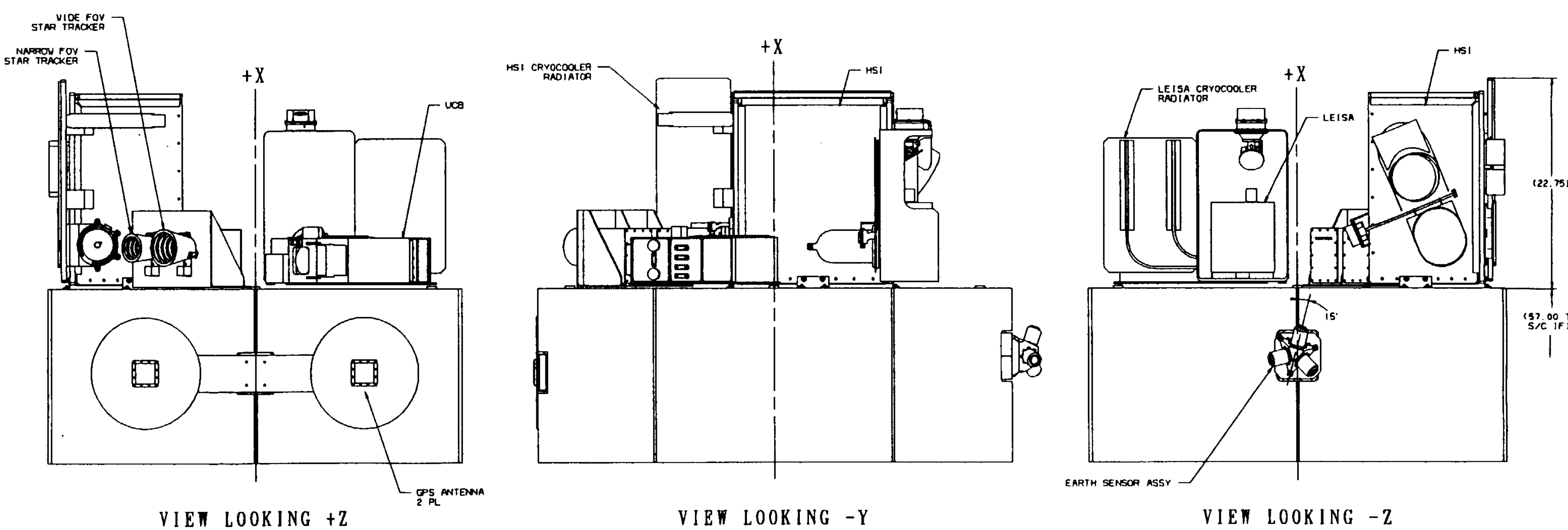
Plan View



VIEW LOOKING -X

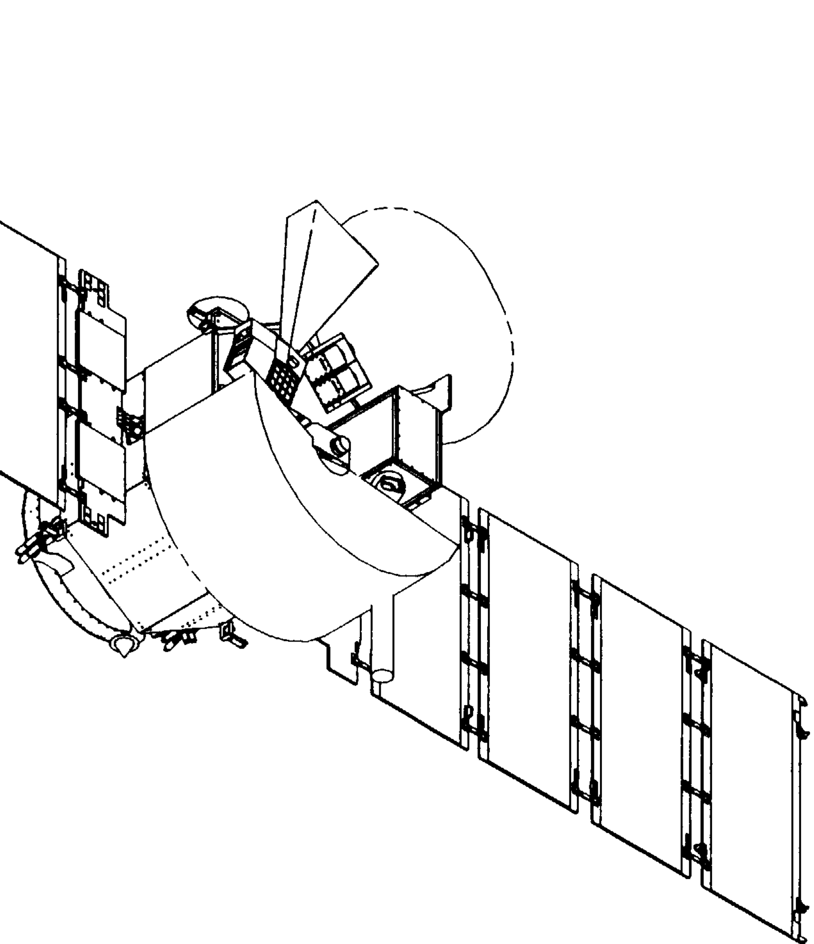
Payload Instrument Layout

Side Views

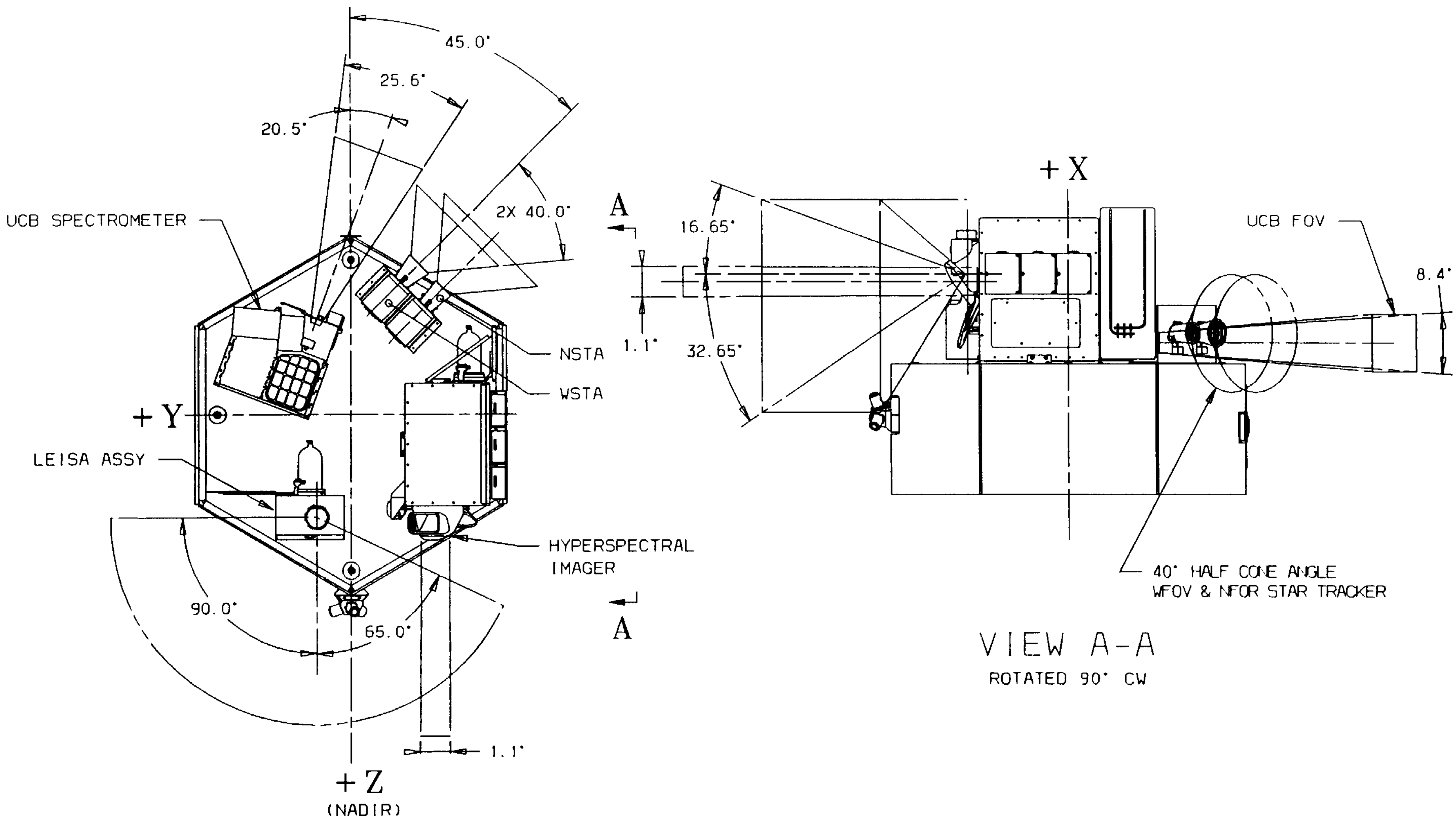


Experiment Field of View's

LEISA FOV	8.8°
OPA Mechanical	+ 6.125° El -14.125° El +87,-60° Az
LEISA FOR	+16.65° El -32.65° El +90,-65° Az
HSI Nadir FOV	1.1°
UCB FOV	8.4° x 25.6°
Star Tracker's	80°



Experiment Field of View's



SSTI

Field of View / Field of Regard Limitations and blockage

TRW

- The following instruments have unobstructed field of views:
  - Hyper Spectral Imager (HSI)
  - Ultraviolet Cosmic Background Spectrograph
  - Coarse Sun Sensors

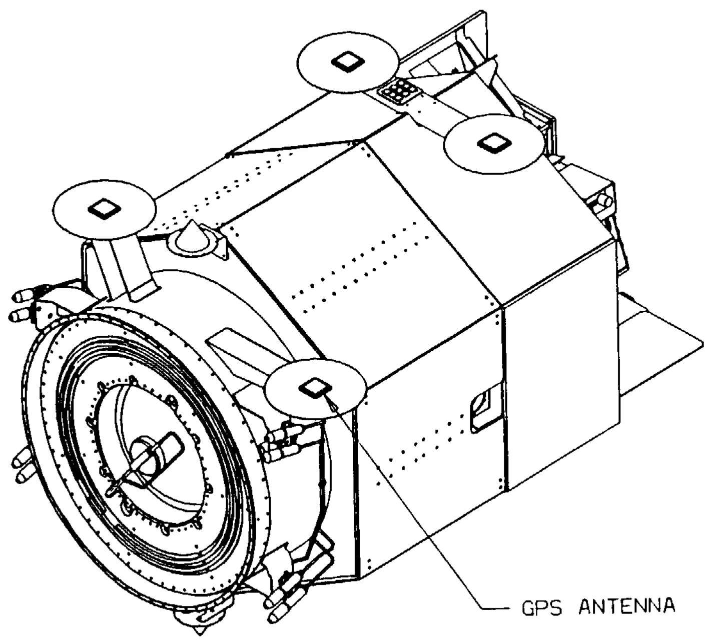
- The following instrument field of view's and or placement on the vehicle are incomplete (i.e. field of view blockage TBD):
  - Narrow and Wide Field of View Star Trackers
  - Earth Sensor Assembly
  - GSTDN (S-Band) Antenna's

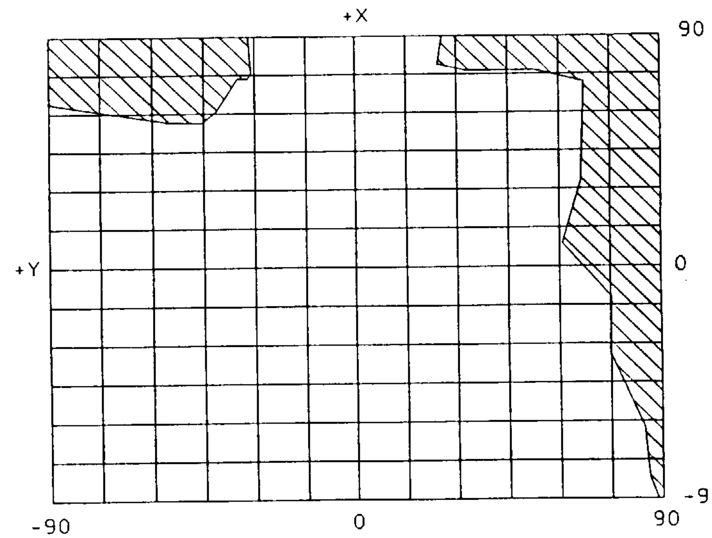
- The Field of Regard of the LEISA Assembly when looking over the limb of the Earth (87° OPA azimuth rotation) will be obstructed by the solar array for approximately 45° of solar array rotation.

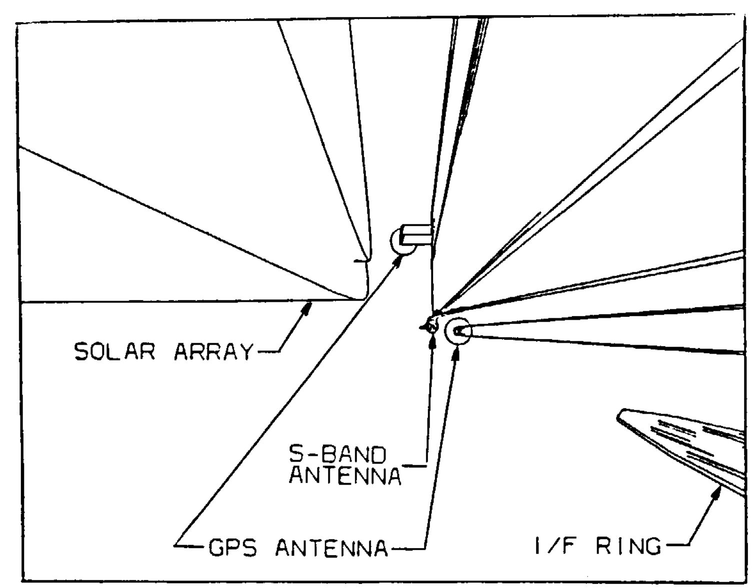
- The Solar array at various angles may potentially partially block the following field's of view: GSTDN (S-Band) Antenna's, GPS Antenna's, Earth Horizon Sensors, and the Star Tracker solar exclusion angle (potential glint).

Field of View Obstructions

Inboard GPS Field of View Blockage



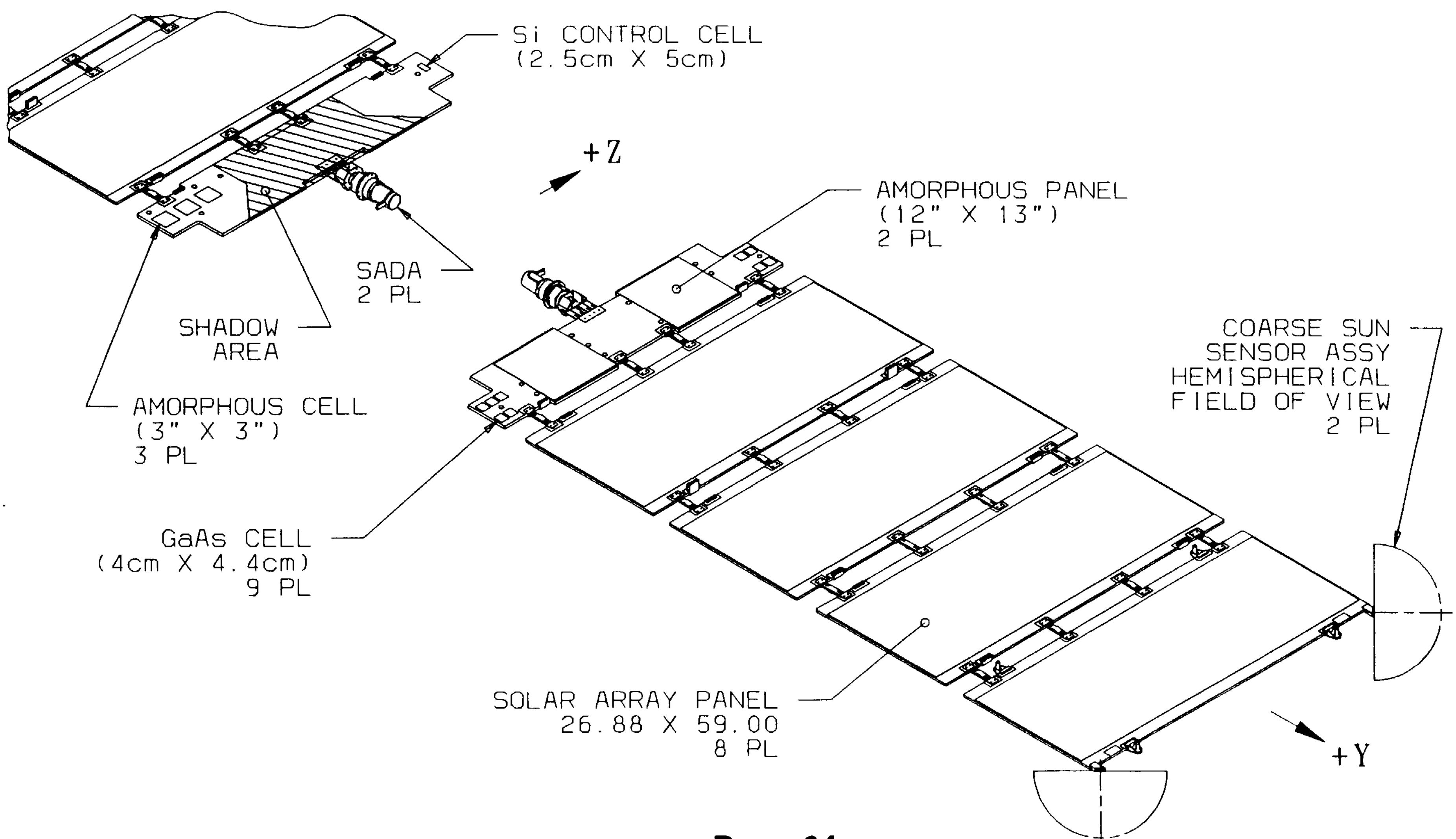




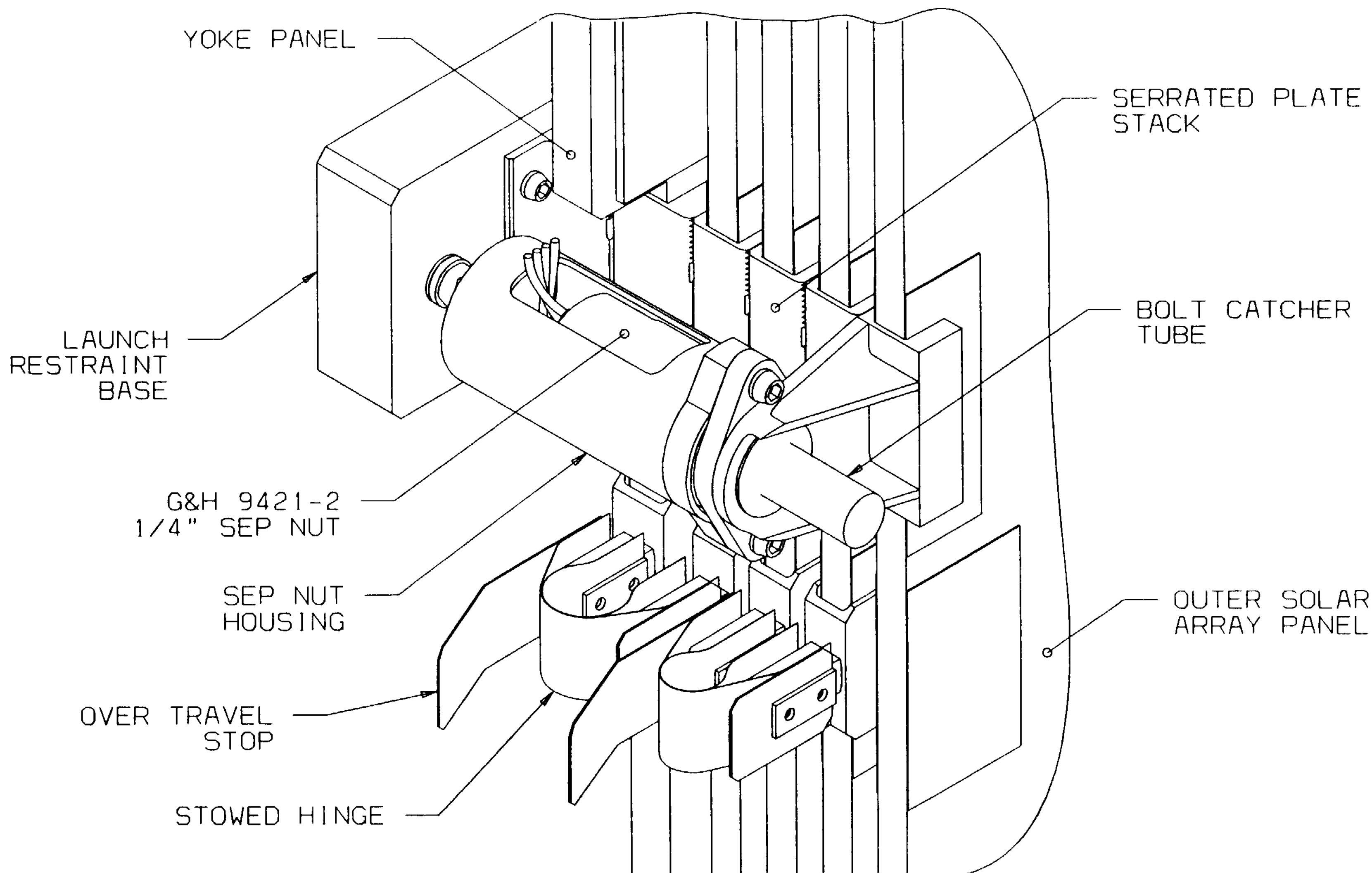
Solar Array Interfaces

- Each solar array wing interfaces with the Avionics Module Structure via a solar array drive assembly (SADA) with 52 slip rings providing 360° of rotation. The spacecraft to solar array electrical interface connectors are located on the inboard side of the yoke.
- In the stowed configuration each solar array wing is restrained via 4 G&H non explosive separation devices (model 9421-2).
- The solar array is deployed in an accordion fashion (uncontrolled) via strain energy hinges with over-travel stops located at the root hinge and between panels .
- The 4 outboard panels of each wing are used for the bus solar cells. The inboard yoke is used for the cell experiments.
- Two coarse sun sensors are mounted on the outboard panel of each wing at 45° angles creating spherical field of view coverage.

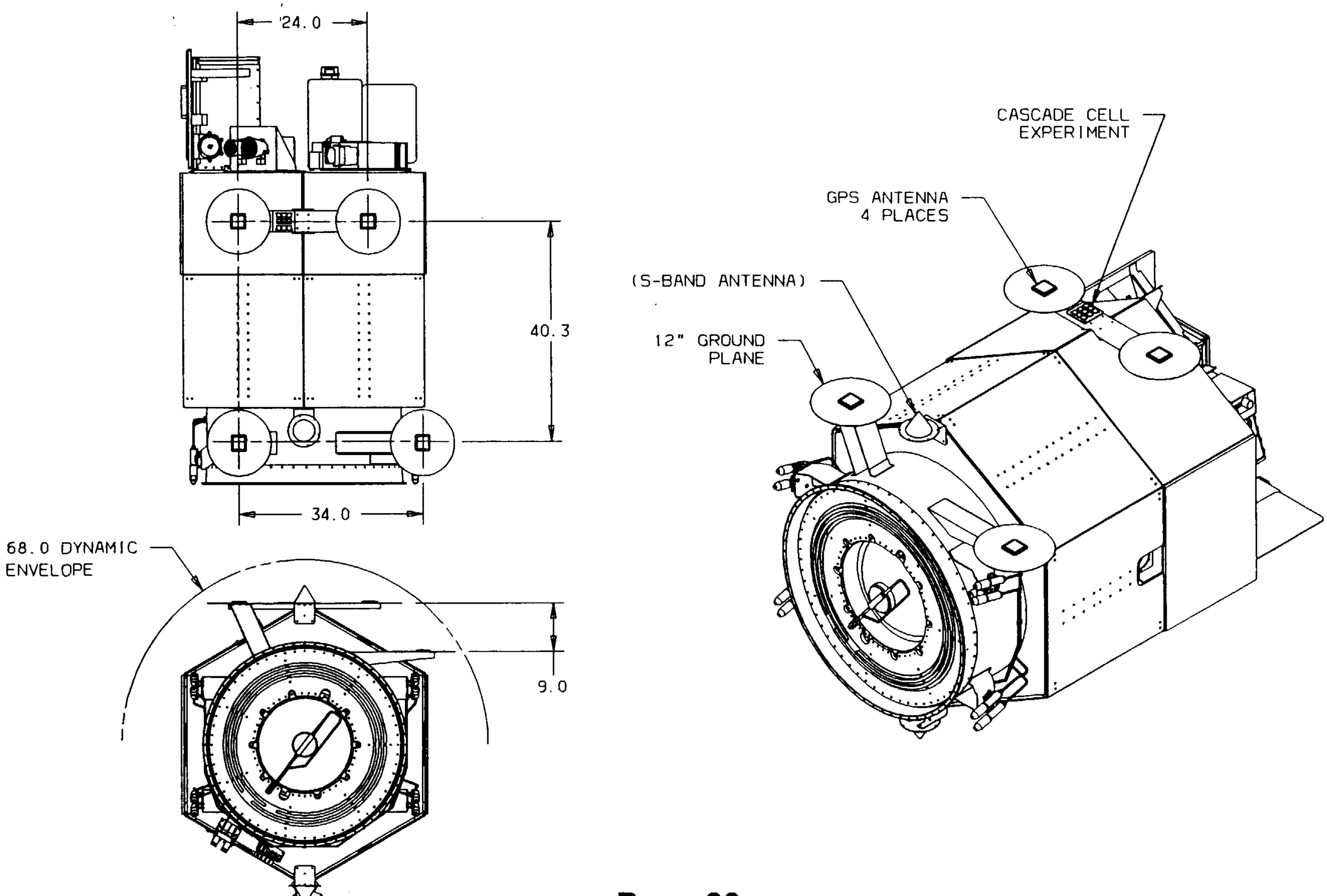
Solar Array Interfaces



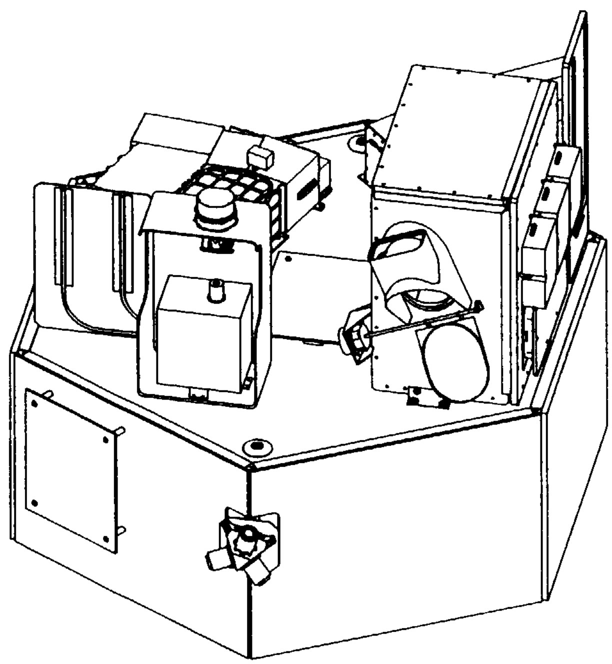
Solar Array Interfaces
Restraint Concept

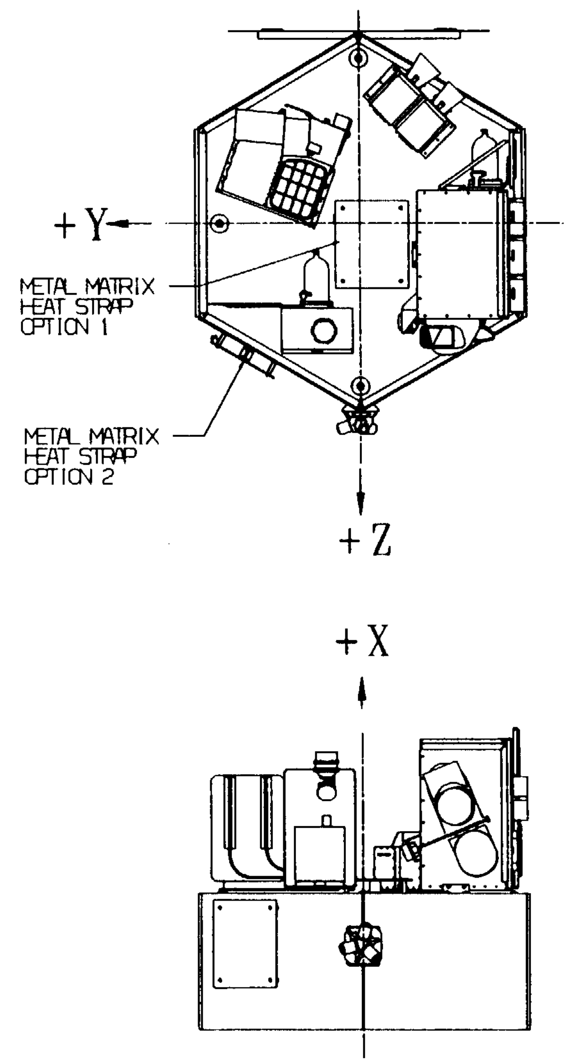


GPS Attitude Determination Layout



Metal Matrix Heat Strap Layout

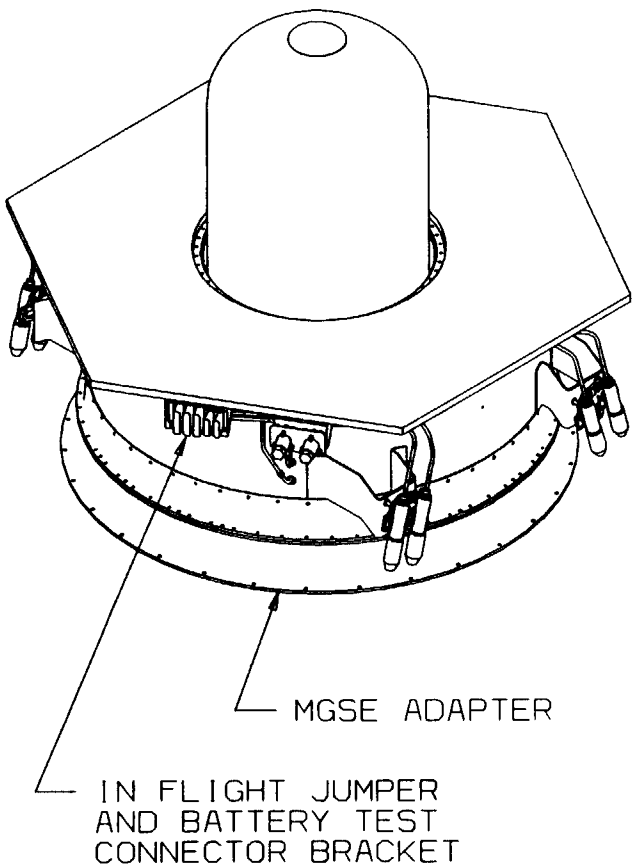


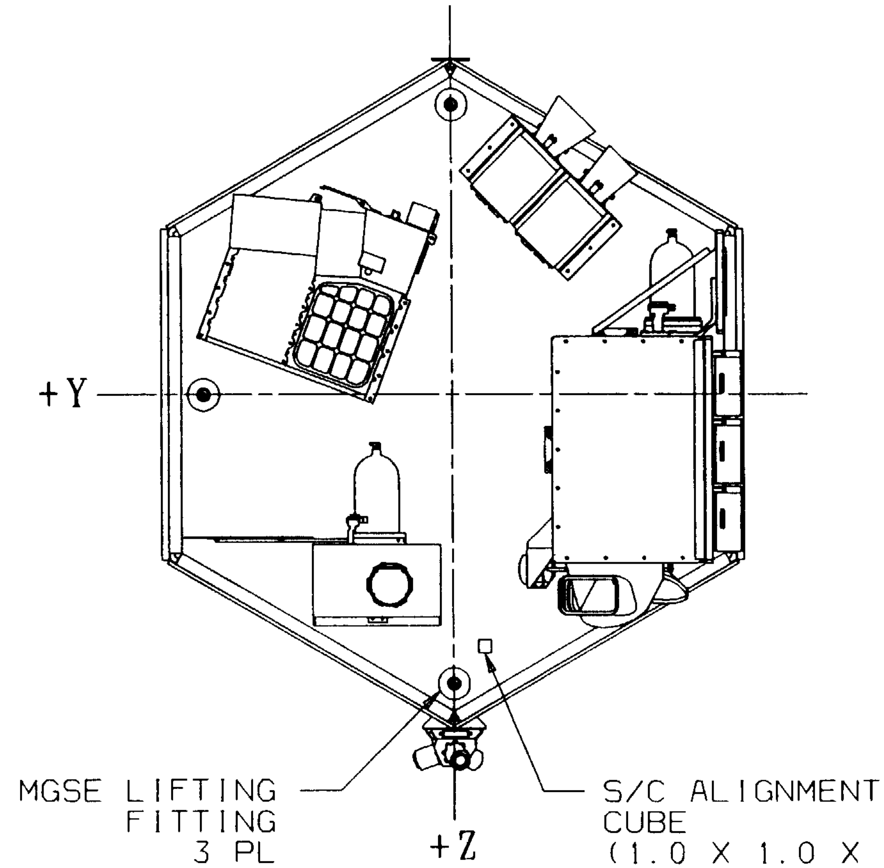


MGSE Interfaces

- Three 1/4 - 28 (TBR) interface points are provided on the payload platform to provide lifting and handling capability.
- A mechanical ground support equipment (MGSE) adapter will mount to the launch vehicle adapter interface providing protection to the interface while allowing for various handling operations and compatibility with existing test equipment interfaces.
- A one inch alignment cube will be attached to the payload platform creating a master reference system for all alignment and knowledge procedures.
- Five in-flight jumper and five (TBR) electrical test connectors are located on the BPM top cover fully accessible from the vehicle's exterior.

Ground Support Equipment I/F's





SSTI

Near Term Tasks

TRW

- Harness roughing for the BPM is due for completion by the end of January, mid February for the AM, and end of February for the payloads and tech demo's.
- A completed layout of the instruments is scheduled for mid February.
- The release of all ICD's and SCD's is scheduled for the end of February.
- Continued support of the Structures and Mechanism's drawing release schedule.
- Begin Installation drawings March 1.

SSTI 1994 MDI LAYOUT SCHEDULE

#	DRAFT	IN CHECK	COMPLETE	DWG #	DRAWING NAME	START	END
1	X	X	X	L305580	SSTI 3D SOLID CATIA MODEL	07/11	OPEN
2	X	X	X	L305581	SSTI CONFIGURATON LAYOUT	07/18	08/05
3	X	X	X		DUAL WING CONFIGURATION LAYOUT	09/05	09/23
4	X	X	X		LLV CONFIGURATON LAYOUT	09/26	10/14
5	X	X	X		BATTERY TRADE (IPV/CPV-5YR)	10/24	11/07
6	X	X	X		BATTERY TRADE (3 CELL/2 CELL)	11/14	12/09

Timeline: JULY 4 11 18 25 · AUGUST 1 8 15 22 29 · SEPTEMBER 5 12 19 26 · OCTOBER 3 10 17 24 31 · NOVEMBER 7 14 21 28 · DECEMBER 5 12 19 26 · JANUARY 1995 2 9 16 23 30

SSTI 1994 MDI ICD/SCD SCHEDULE

#	DRAFT	IN CHECK	RELEASED	DWG #	DRAWING NAME		START	END
1	X			C305602	UCB SPECTROMETER		11/28	12/16
2	X	X		C305603	UCB ELECTRONICS BOX		11/21	12/02
3				C305604	MICROMACHINED ACCELEROMETERS		11/21	12/02
4	X			C305605	LEISA		12/19	01/06
5				C305606				
6				C305607	WFOV STAR TRACKER		12/12	12/23
7				C305608	NFOV STAR TRACKER		12/12	12/23
8	X	X		C305609	GODDARD ELECTRONICS MODULE		11/14	12/02
9	X	X		C305610	GPS RECEIVER		11/21	12/02
10				C305611	MULTI JUNCTION CELL ASSY		12/12	01/02
11	X	X		C305612	METAL MATRIX HEAT STRAP		11/14	11/25
12	X	X		C305613	GAS PROPORTIONAL COUNTER		12/05	12/16
13	X	X		C305614	GPS ANTENNA		11/07	11/18
14	X	X		C305615	POWER CONTROL UNIT		09/26	10/14
15	X	X		C305616	SOLAR ARRAY REGULATOR		08/01	08/19
16	X	X		C305617	DEPLOYMENT DEVICE CONTROLLER		08/01	08/19
17	X	X		C305618	DATA INTERFACE UNIT		08/01	08/19
18	X	X		C305619	GSTDN TRANSPONDER		08/08	08/26
19	X	X		C305620	RF SWITCHING ASSY		08/08	08/26
20	X	X	X	C305621	CONTROL ELECTRONICS ASSY		08/08	08/26
21	X	X	X	C305622	REACTION WHEEL ASSY		08/15	09/02
22	X	X	X	C305623	MAGNETIC TORQUER		08/15	09/02
23	X	X	X	C305624	GRYO REFERENCE ASSY		08/15	09/02
24	X	X		C305625	EARTH HORIZON SENSOR		12/05	12/16
25	X	X	X	C305626	TAM SENSOR		08/29	09/09
26	X	X	X	C305627	TAM ELECTRONICS		08/29	09/09
27	X			C305628	SOLAR ARRAY DRIVE ASSY		09/12	09/30
28	X	X		C305629	S-BAND ANTENNA		09/12	09/30
29	X	X	X	305630	SPACECRAFT COMPUTER		08/29	09/16
30	X	X	X	305631	VALVE DRIVE ELECTRONICS		09/19	10/07
31	X	X		305632	SOLAR ARRAY DRIVE ELECT		09/19	10/07
32	X	X	X	305633	NIH2 BATTERY MODULE		08/29	09/16
33	X	X		305634	THIN FILM CELL ASSY		12/05	12/16
34	X	X		C305635	PHOTOVOLTAIC REGULATOR KIT EXP		11/28	12/16
35	X	X	X	305636	PAYLOAD ELECTRONICS ASSY		09/05	09/23
36	X			305637	SOLID STATE RECORDER		09/26	10/14
37	X	X	X	305638	MAGNETICALLY SUSPENDED RWA		09/05	09/23
38	X	X		305639	CRYOCOOLER (LISA)		09/05	09/23
39	X	X		305640	OPTICAL POINTING ASSY (LISA)		09/12	09/30
40	X			305641	HSI SENSOR ASSY		11/28	12/23
41	X			305642	COARSE SUN SENSOR (816737)		10/03	10/28
42	X	X		305643	SPACECRAFT STRUCTURE	**	11/14	12/02
43	X	X	X	305644	PROPULSION MODULE	**	11/21	12/09
44	X	X		305645	SOLAR ARRAY	**	11/28	12/16
45				305646	DC HARNESS	**	12/05	12/23
46				305647	RF HARNESS	**	12/12	01/06
47				305648	FIBER OPTIC DATA BUS	**	12/19	01/13
48	X			305649	LAUNCH VEHICLE ICD		12/19	01/13
49	X	X		305650	HSI CONTROL ELECTRONICS		12/19	01/13
50	X	X		305651	HSI POWER CONVERTER ELECTRONICS		12/19	01/13
51				C305652				
52				C305653				
53	X	X		C305654	GPS QUAD PREAMP			
54				C305655	ADVANCED PACKAGING EXPERIMENT			

Timeline: AUGUST 1 8 15 22 29 · SEPTEMBER 5 12 19 26 · OCTOBER 3 10 17 24 31 · NOVEMBER 7 14 21 28 · DECEMBER 5 12 19 26 · JANUARY 1995 2 9 16 23 30 · FEBRUARY 6 13 20 27

SSTI 1995 MDI INSTL DWG SCHEDULE

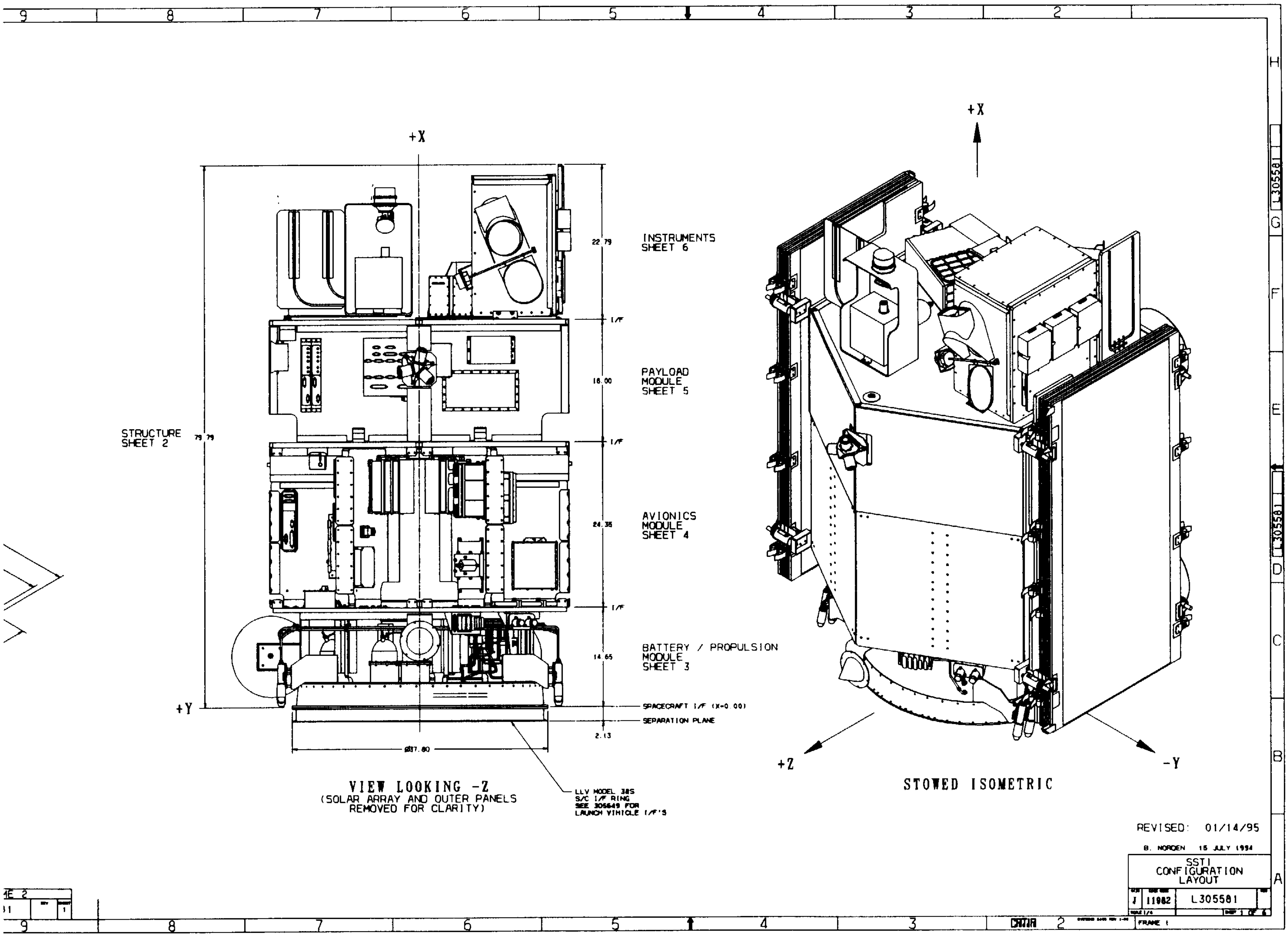
#	DRAFT	IN CHECK	RELEASED	DWG #	DRAWING NAME	ORDER OF ASSY 1	2	3	4
1				305601	LAUNCH VEHICLE INSTL	X			
2				305600	SPACECRAFT COMPLETE INSTL		X		
3				305599	PROPULSION MODULE INSTL			X	
4				305598	BATTERY MODULE INSTL			X	
5				305597	AVIONICS MODULE INSTL			X	
6				305596	PAYLOAD MODULE INSTL			X	
7									
8									

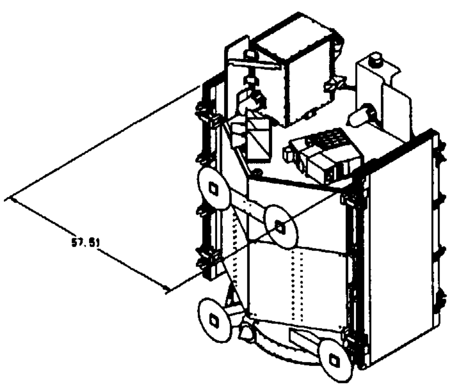
Timeline: MARCH 6 13 20 27 · APRIL 3 10 17 24 · MAY 1 8 15 22 29 · JUNE 5 12 19 26 · JULY 3 10 17 24 31 · AUGUST 7 14 21 28 · SEPTEMBER 4 11 18 25

** CATIA MODEL ONLY

MODIFIED: 01/15/95

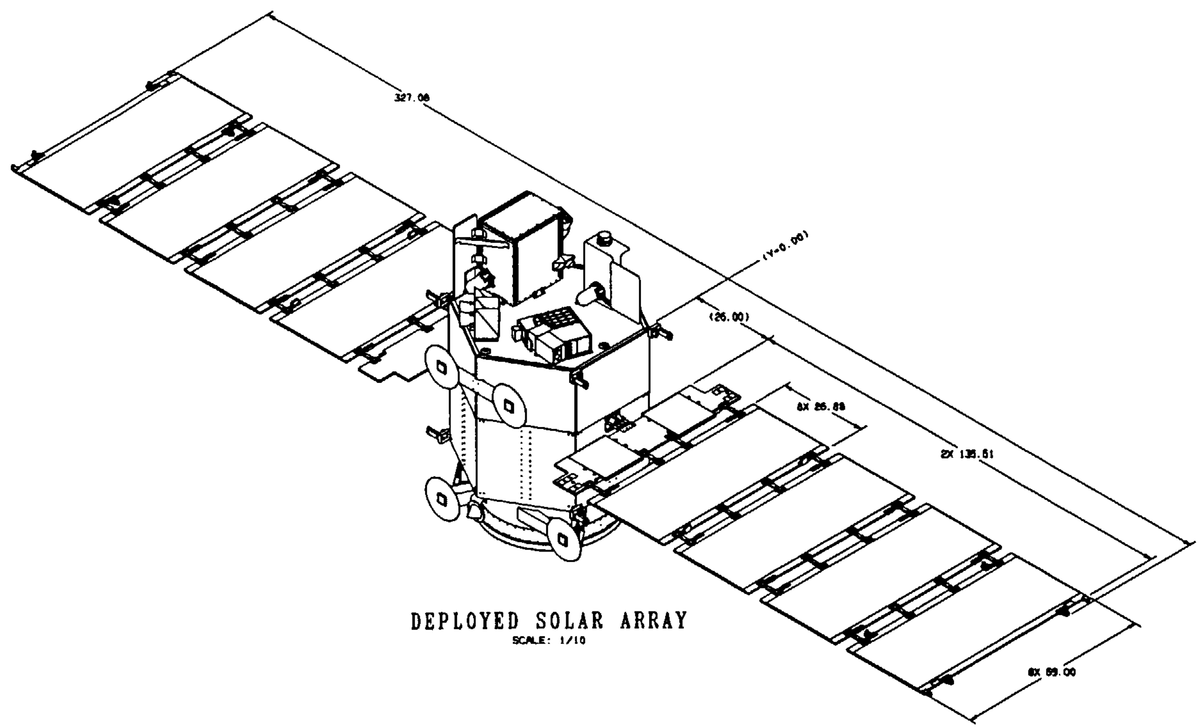
Appendix


+X
STRUCTURE
SHEET 2
79.79
22.79
INSTRUMENTS
SHEET 6
I/F
18.00
PAYLOAD
MODULE
SHEET 5
I/F
24.35
AVIONICS
MODULE
SHEET 4
I/F
14.65
BATTERY / PROPULSION
MODULE
SHEET 3
+Y
SPACECRAFT I/F (X=0.00)
SEPARATION PLANE
2.13
Ø37.80
LLV MODEL 38S
S/C I/F RING
SEE 305649 FOR
LAUNCH VIHICLE I/F'S
VIEW LOOKING -Z
(SOLAR ARRAY AND OUTER PANELS
REMOVED FOR CLARITY)
+X
+Z
-Y
STOWED ISOMETRIC
REVISED: 01/14/95
B. NORDEN 15 JULY 1994
SSTI
CONFIGURATION
LAYOUT
J
11982
L305581
SHEET 1 OF 6
FRAME 1
L305581



STOWED SOLAR ARRAY

SCALE: 1/10



DEPLOYED SOLAR ARRAY

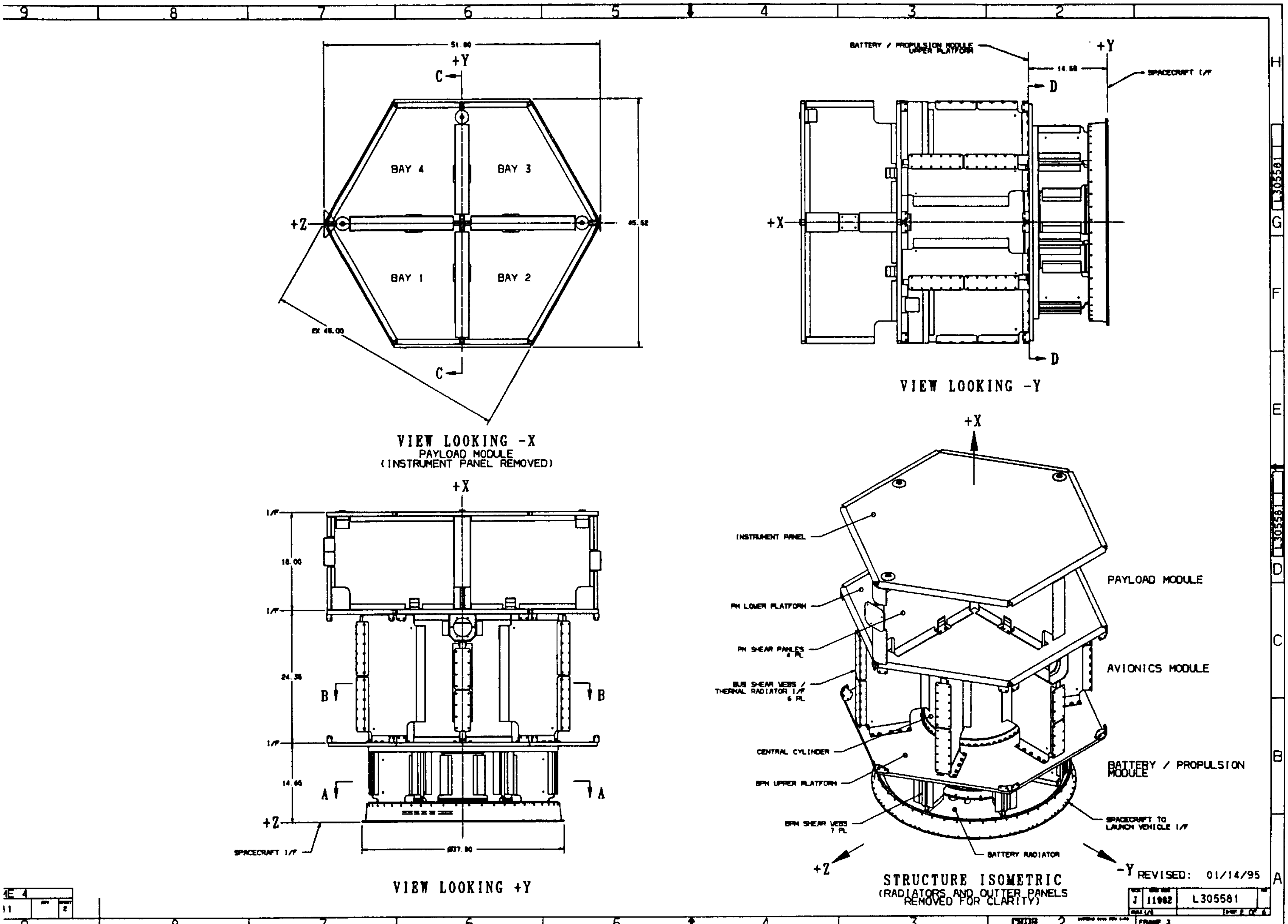
SCALE: 1/10

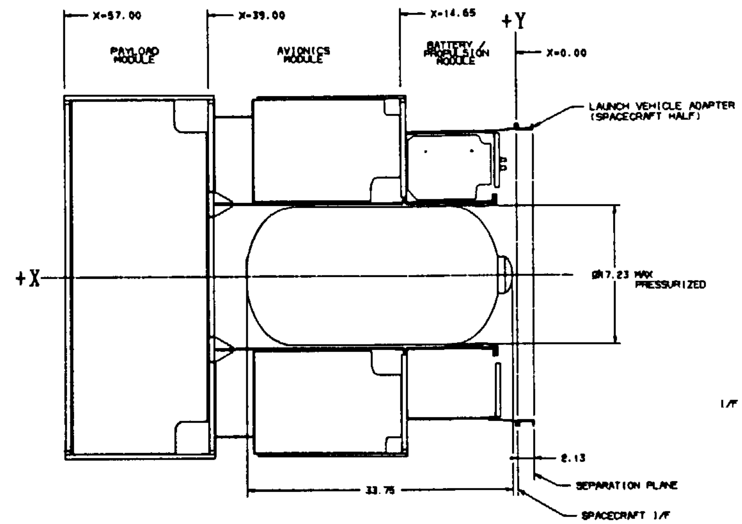
STRUCTURE
SHEET 2

+Y

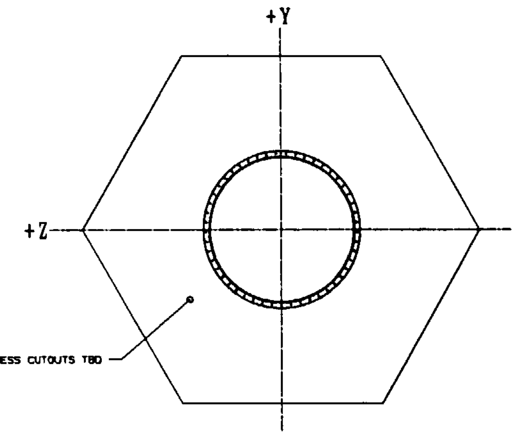
FRAME 2

L305581

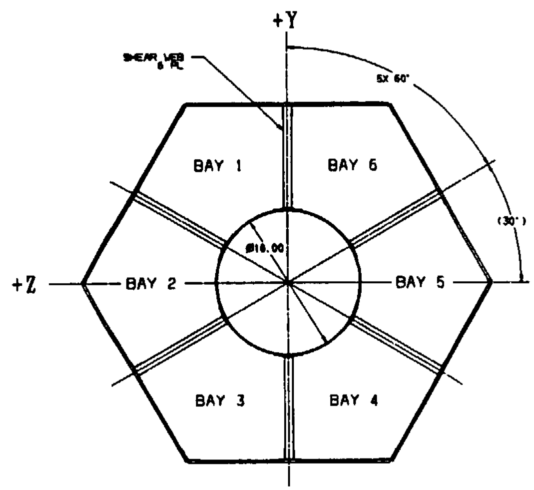

VIEW LOOKING -X
PAYLOAD MODULE
(INSTRUMENT PANEL REMOVED)
BAY 1
BAY 2
BAY 3
BAY 4
VIEW LOOKING -Y
BATTERY / PROPULSION MODULE UPPER PLATFORM
SPACECRAFT I/F
VIEW LOOKING +Y
STRUCTURE ISOMETRIC
(RADIATORS AND OUTTER PANELS REMOVED FOR CLARITY)
INSTRUMENT PANEL
PM LOWER PLATFORM
PM SHEAR PANLES 4 PL
BUS SHEAR WEBS / THERMAL RADIATOR I/F 6 PL
CENTRAL CYLINDER
BPM UPPER PLATFORM
BPM SHEAR WEBS 7 PL
BATTERY RADIATOR
SPACECRAFT TO LAUNCH VEHICLE I/F
PAYLOAD MODULE
AVIONICS MODULE
BATTERY / PROPULSION MODULE
REVISED: 01/14/95
L305581



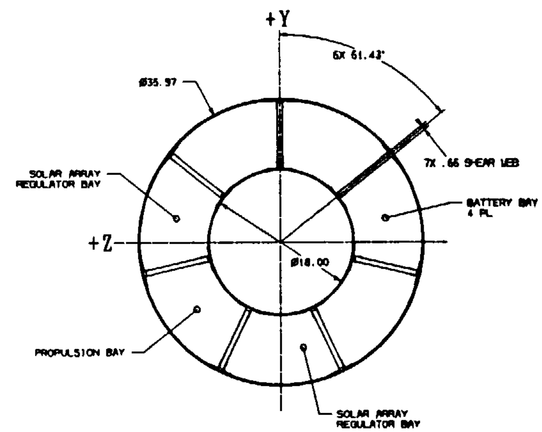
SECTION C-C
STRUCTURE CROSS SECTION



VIEW D-D

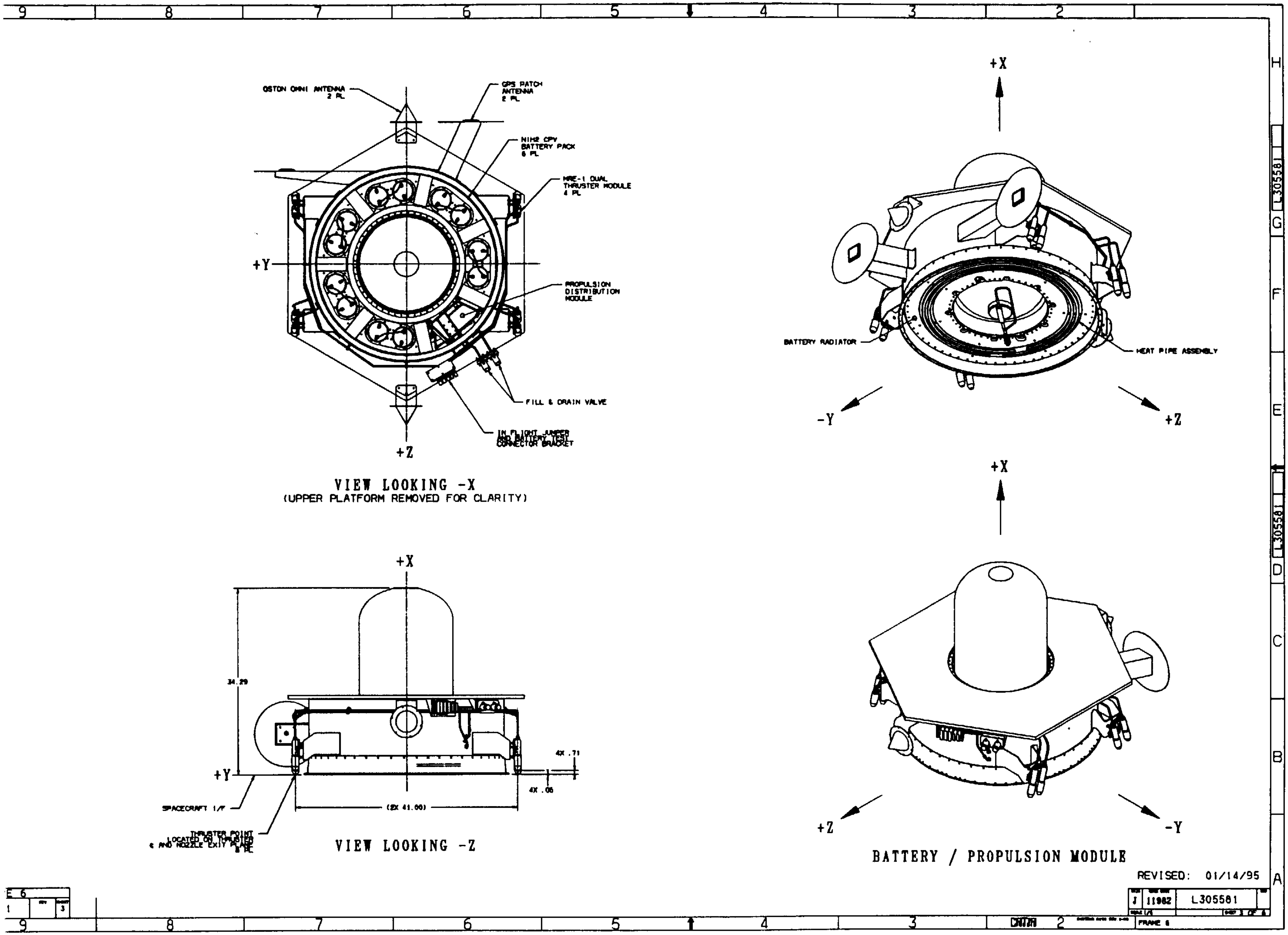


SECTION B-B
AVIONICS MODULE

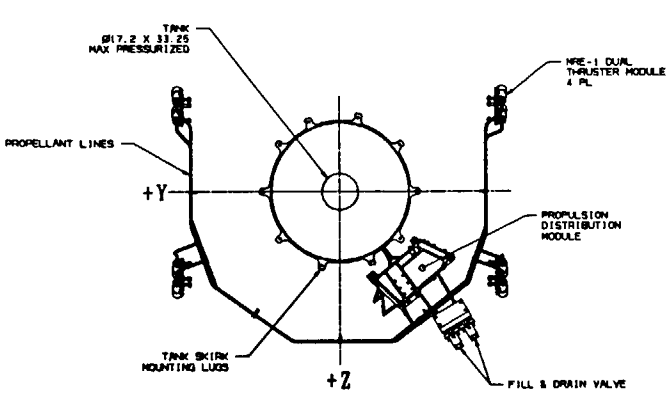


SECTION A-A
BATTERY / PROPULSION MODULE

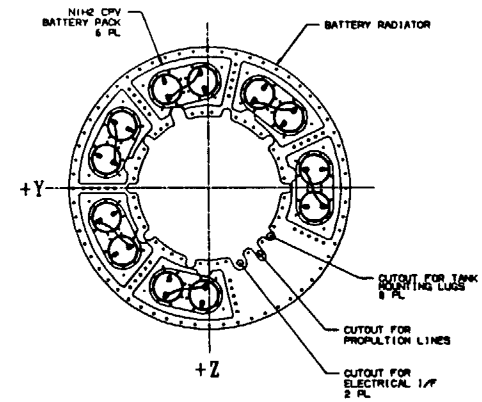
FRAME 4
L305581



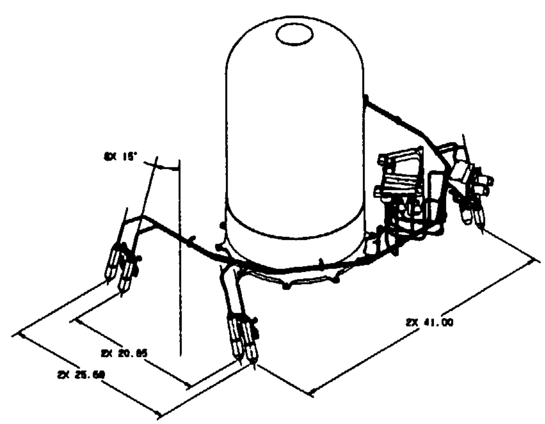
OSTON OMNI ANTENNA 2 PL
GPS PATCH ANTENNA 2 PL
NIH2 CPV BATTERY PACK 6 PL
MRE-1 DUAL THRUSTER MODULE 4 PL
PROPULSION DISTRIBUTION MODULE
FILL & DRAIN VALVE
IN FLIGHT JUMPER AND BATTERY TEST CONNECTOR BRACKET
+Y
+Z
VIEW LOOKING -X
(UPPER PLATFORM REMOVED FOR CLARITY)
+X
34.29
+Y
SPACECRAFT I/F
THRUSTER POINT LOCATED ON THRUSTER ¢ AND NOZZLE EXIT PLANE 8 PL
(2X 41.00)
4X .71
4X .06
VIEW LOOKING -Z
+X
BATTERY RADIATOR
HEAT PIPE ASSEMBLY
-Y
+Z
+X
+Z
-Y
BATTERY / PROPULSION MODULE
REVISED: 01/14/95
J 11982 L305581
FRAME 6
L305581



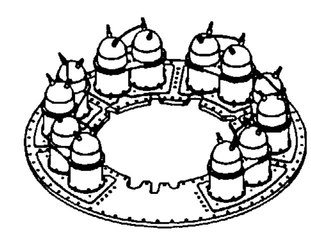
VIEW LOOKING -X
PROPULSION MODULE



VIEW LOOKING -X
BPM EQUIPMENT

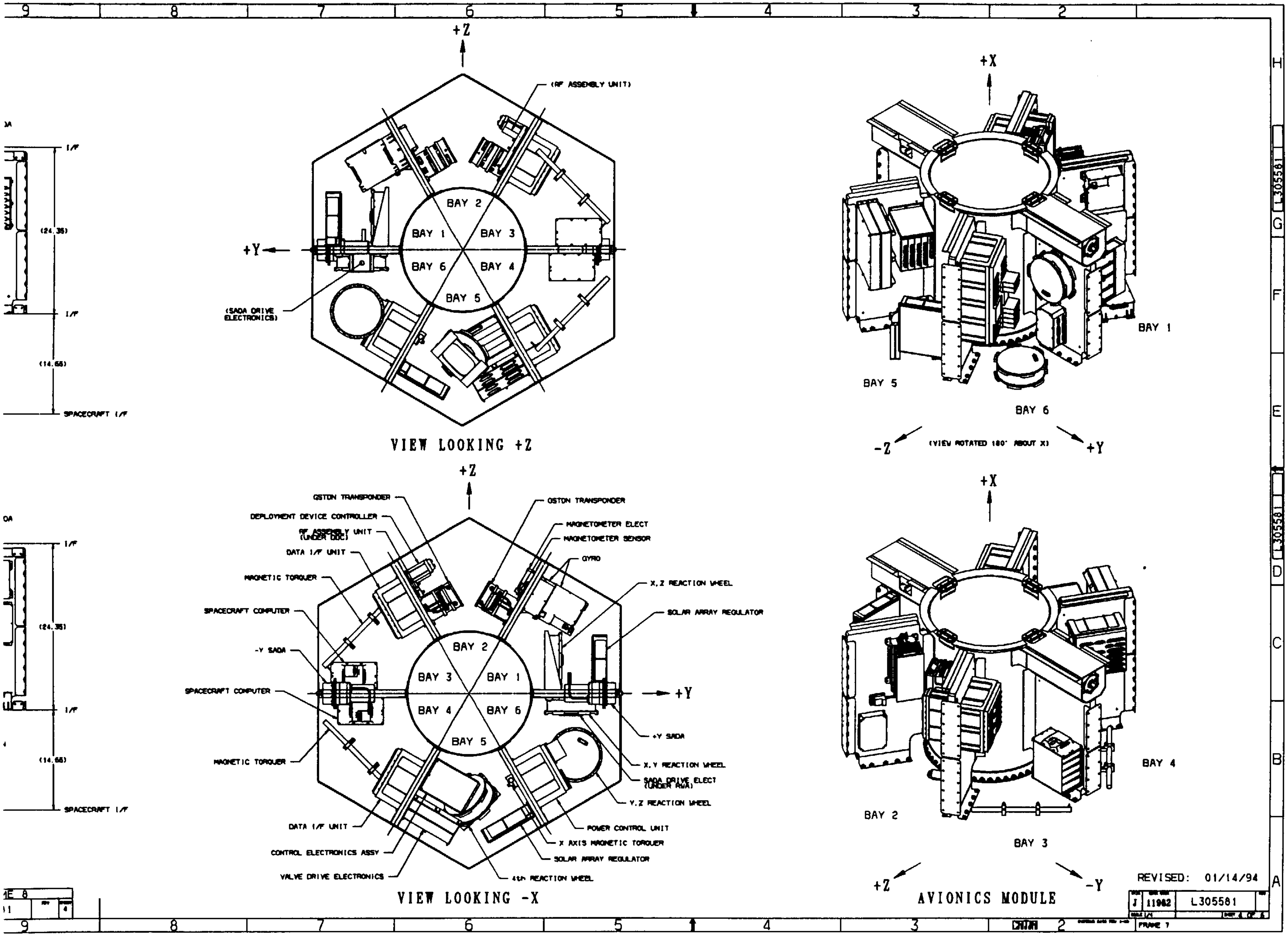


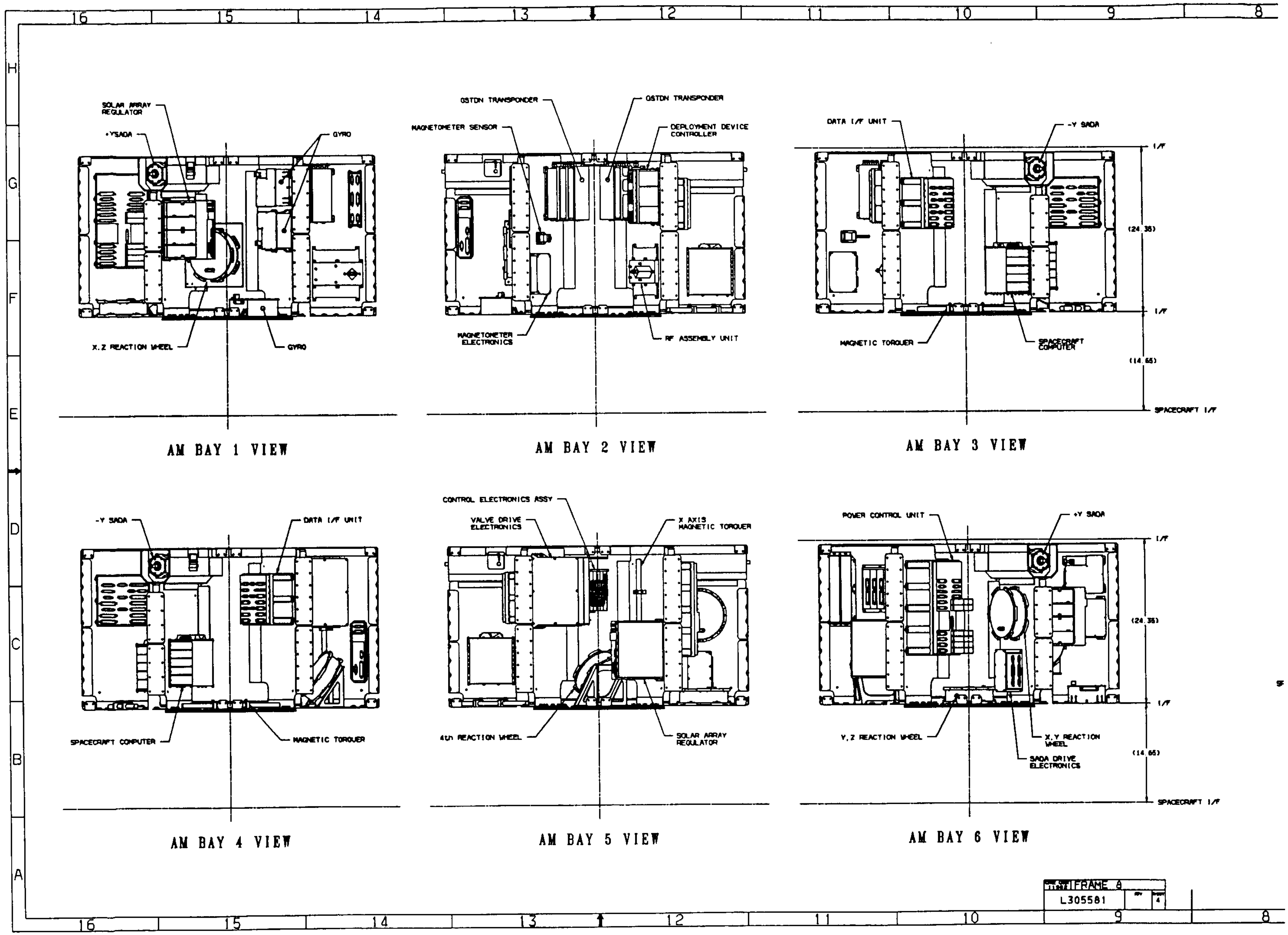
PROPULSION MODULE ISO



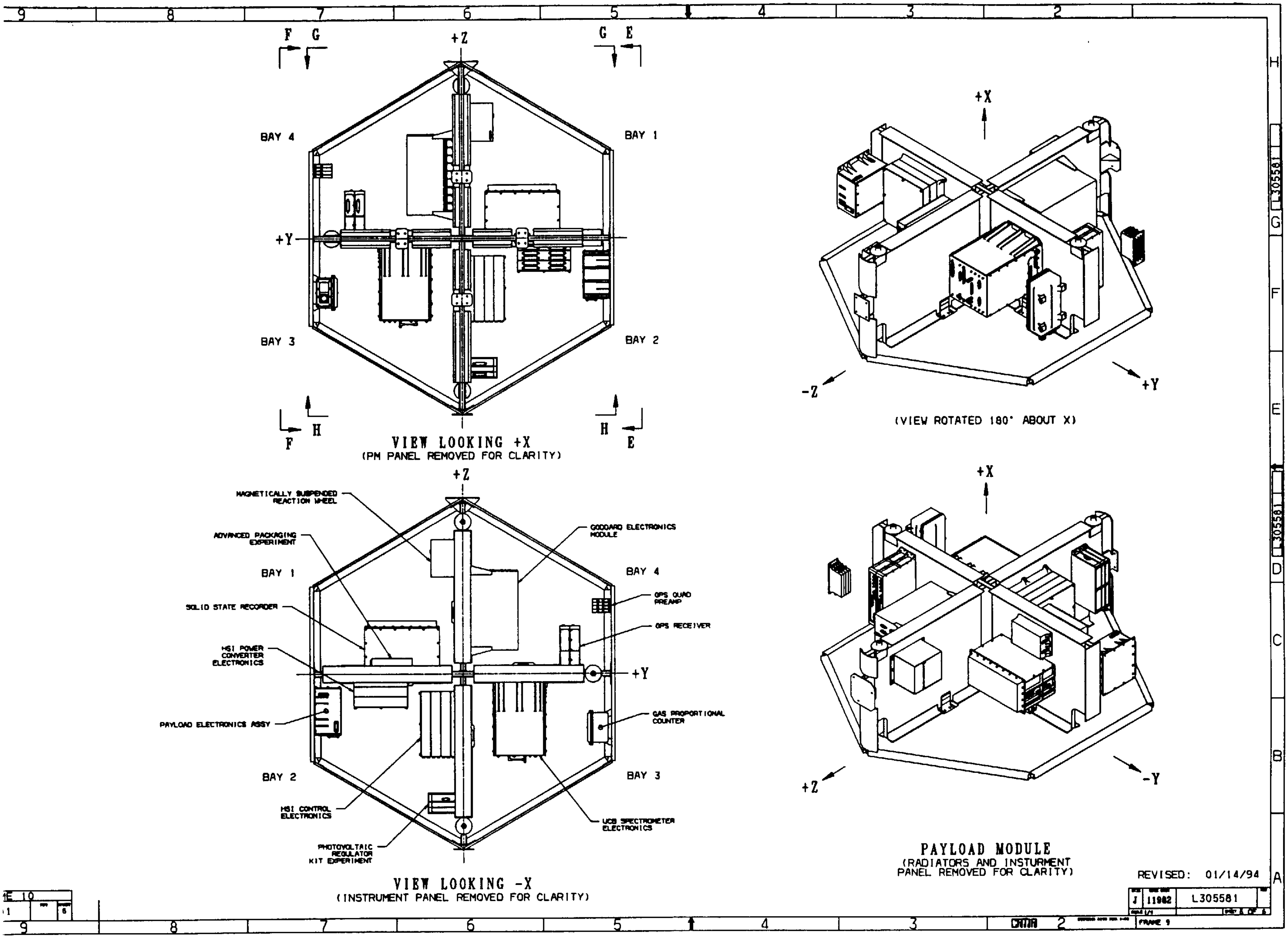
BPM EQUIPMENT ISO

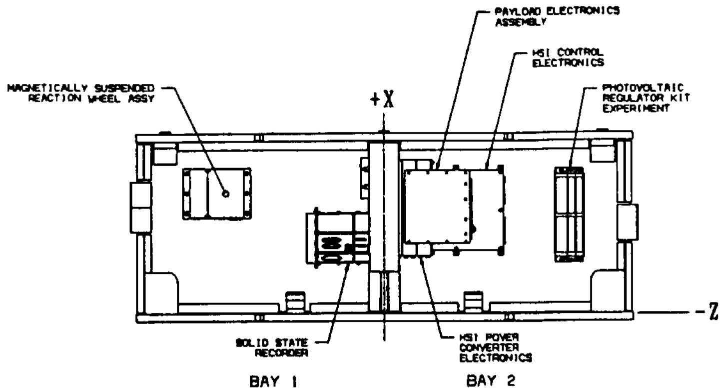
FRAME 6
L305581


VIEW LOOKING +Z
+Z
+Y
BAY 1
BAY 2
BAY 3
BAY 4
BAY 5
BAY 6
(RF ASSEMBLY UNIT)
(SADA DRIVE ELECTRONICS)
VIEW LOOKING -X
OSTON TRANSPONDER
DEPLOYMENT DEVICE CONTROLLER
RF ASSEMBLY UNIT (UNDER DDC)
DATA I/F UNIT
MAGNETIC TORQUER
SPACECRAFT COMPUTER
-Y SADA
MAGNETOMETER ELECT
MAGNETOMETER SENSOR
GYRO
X,Z REACTION WHEEL
SOLAR ARRAY REGULATOR
+Y SADA
X,Y REACTION WHEEL
SADA DRIVE ELECT (UNDER RWA)
Y,Z REACTION WHEEL
POWER CONTROL UNIT
X AXIS MAGNETIC TORQUER
4th REACTION WHEEL
CONTROL ELECTRONICS ASSY
VALVE DRIVE ELECTRONICS
+X
-Z
(VIEW ROTATED 180° ABOUT X)
-Y
I/F
(24.35)
(14.66)
SPACECRAFT I/F
AVIONICS MODULE
REVISED: 01/14/94
11982
L305581
FRAME 7

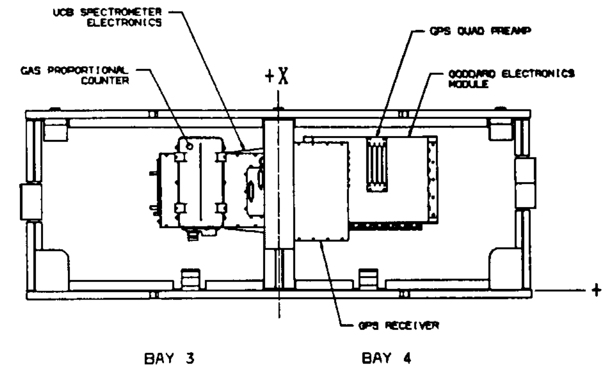


SOLAR ARRAY REGULATOR
+YSADA
GYRO
X,Z REACTION WHEEL
GYRO
AM BAY 1 VIEW
GSTDN TRANSPONDER
GSTDN TRANSPONDER
MAGNETOMETER SENSOR
DEPLOYMENT DEVICE CONTROLLER
MAGNETOMETER ELECTRONICS
RF ASSEMBLY UNIT
AM BAY 2 VIEW
DATA I/F UNIT
-Y SADA
I/F
(24.35)
I/F
MAGNETIC TORQUER
SPACECRAFT COMPUTER
(14.65)
SPACECRAFT I/F
AM BAY 3 VIEW
-Y SADA
DATA I/F UNIT
SPACECRAFT COMPUTER
MAGNETIC TORQUER
AM BAY 4 VIEW
CONTROL ELECTRONICS ASSY
VALVE DRIVE ELECTRONICS
X AXIS MAGNETIC TORQUER
4th REACTION WHEEL
SOLAR ARRAY REGULATOR
AM BAY 5 VIEW
POWER CONTROL UNIT
+Y SADA
I/F
(24.35)
I/F
Y,Z REACTION WHEEL
X,Y REACTION WHEEL
SADA DRIVE ELECTRONICS
(14.65)
SPACECRAFT I/F
AM BAY 6 VIEW
FRAME A
L305581
4

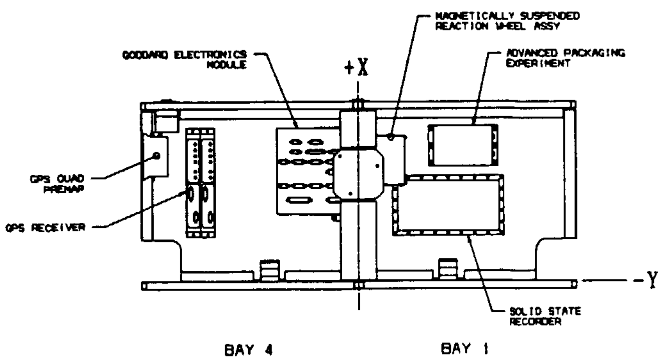

VIEW LOOKING +X
(PM PANEL REMOVED FOR CLARITY)
BAY 1
BAY 2
BAY 3
BAY 4
+Z
+Y
F G
G E
F H
H E
VIEW LOOKING -X
(INSTRUMENT PANEL REMOVED FOR CLARITY)
MAGNETICALLY SUSPENDED REACTION WHEEL
ADVANCED PACKAGING EXPERIMENT
SOLID STATE RECORDER
HSI POWER CONVERTER ELECTRONICS
PAYLOAD ELECTRONICS ASSY
HSI CONTROL ELECTRONICS
PHOTOVOLTAIC REGULATOR KIT EXPERIMENT
GODDARD ELECTRONICS MODULE
GPS QUAD PREAMP
GPS RECEIVER
GAS PROPORTIONAL COUNTER
UCB SPECTROMETER ELECTRONICS
+X
-Z
-Y
(VIEW ROTATED 180° ABOUT X)
PAYLOAD MODULE
(RADIATORS AND INSTURMENT PANEL REMOVED FOR CLARITY)
REVISED: 01/14/94
J 11982 L305581
FRAME 9
L305581



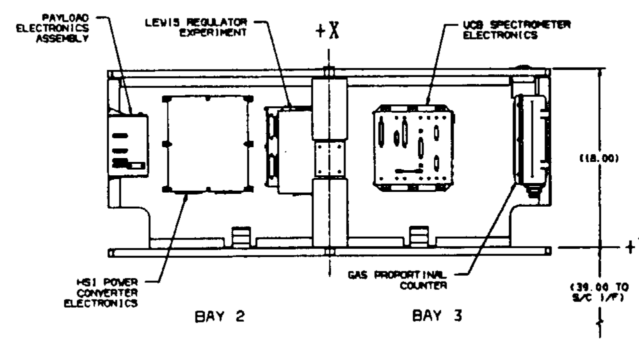
VIEW E-E
VIEW ROTATED 90° CCW
(RADIATOR PANELS REMOVED FOR CLARITY)



VIEW F-F
VIEW ROTATED 90° CW
(RADIATOR PANELS REMOVED FOR CLARITY)



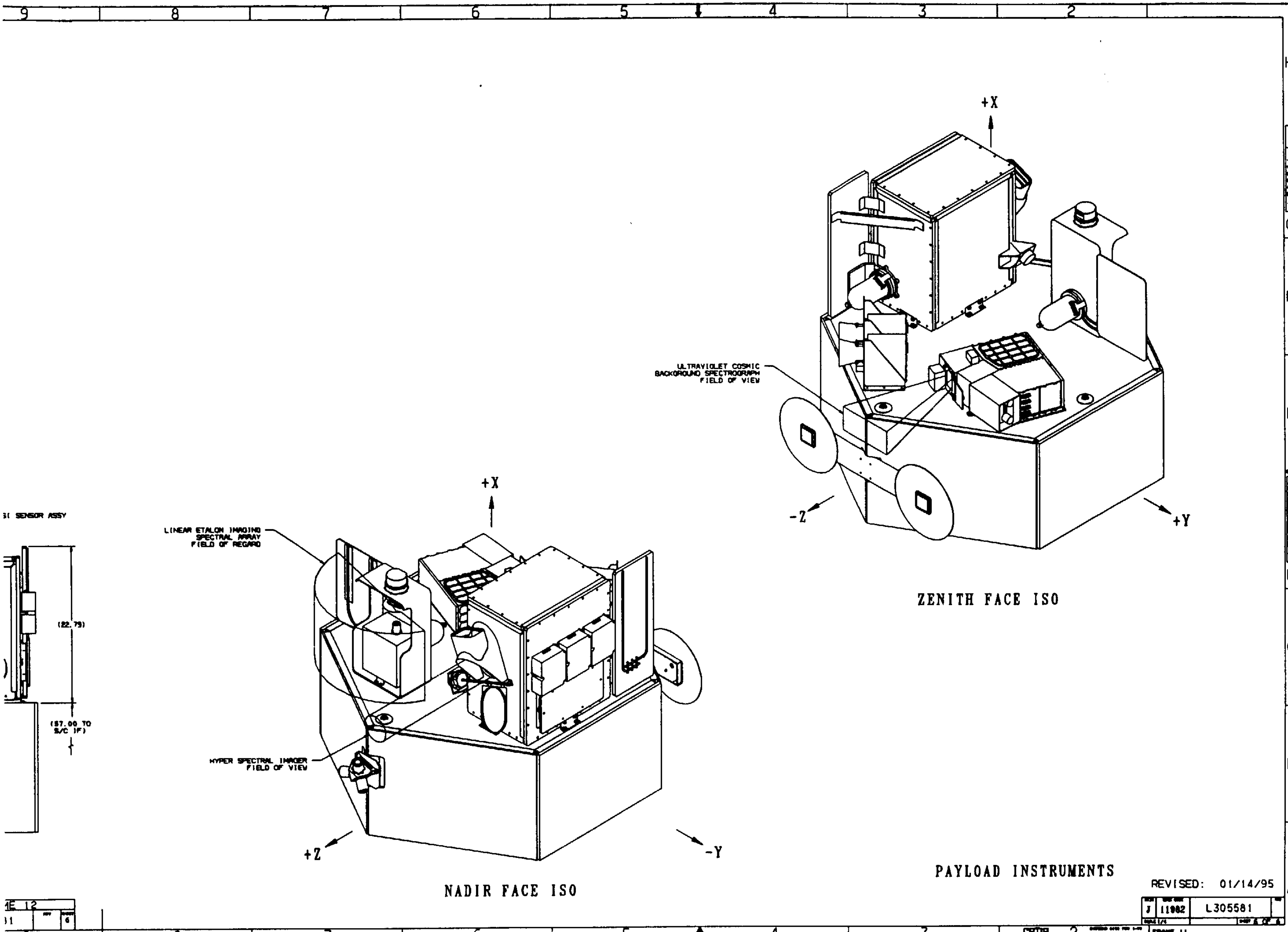
VIEW G-G
(RADIATORS REMOVED FOR CLARITY)

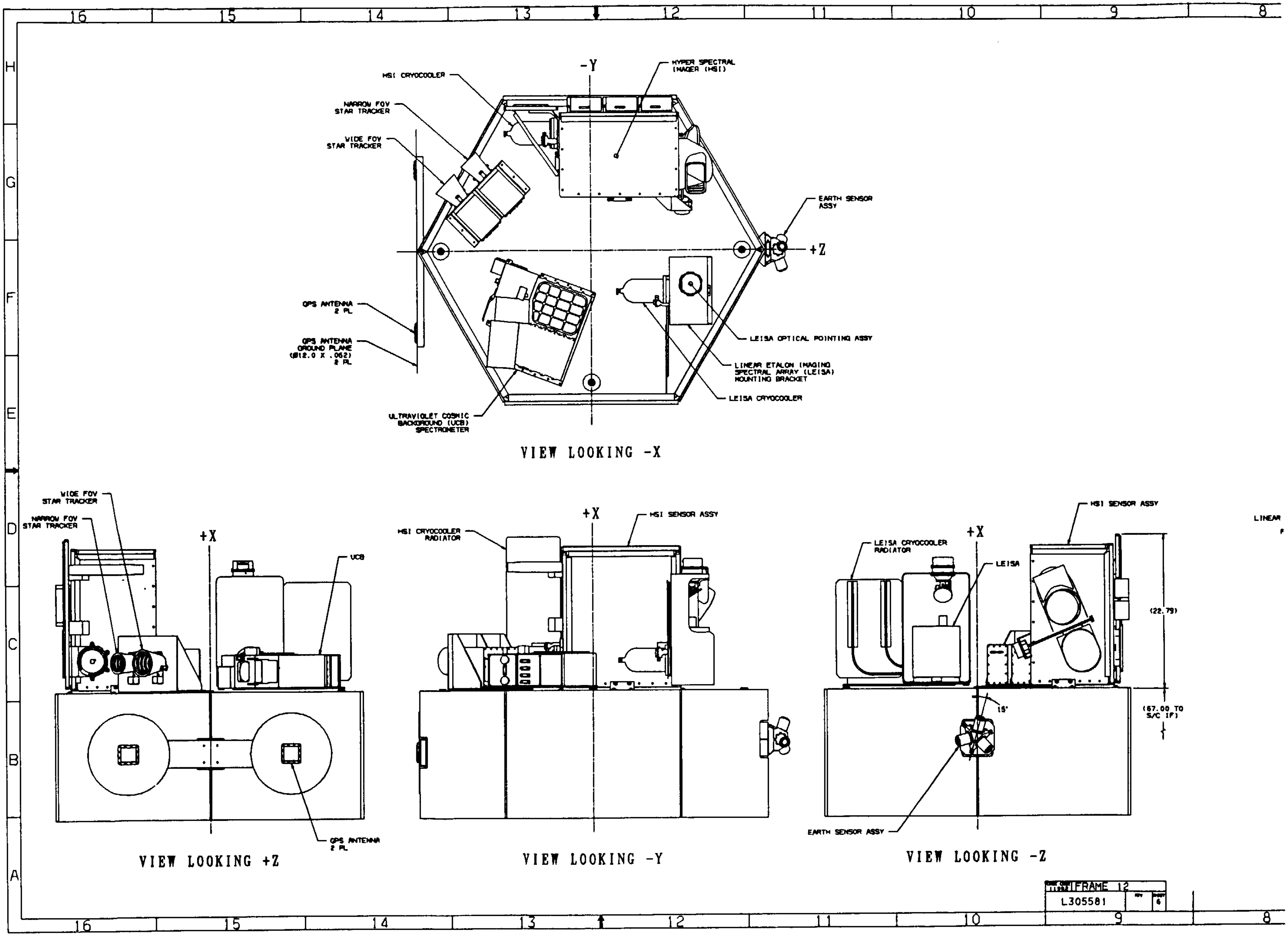


VIEW H-H
VIEW ROTATED 180°
(RADIATORS REMOVED FOR CLARITY)

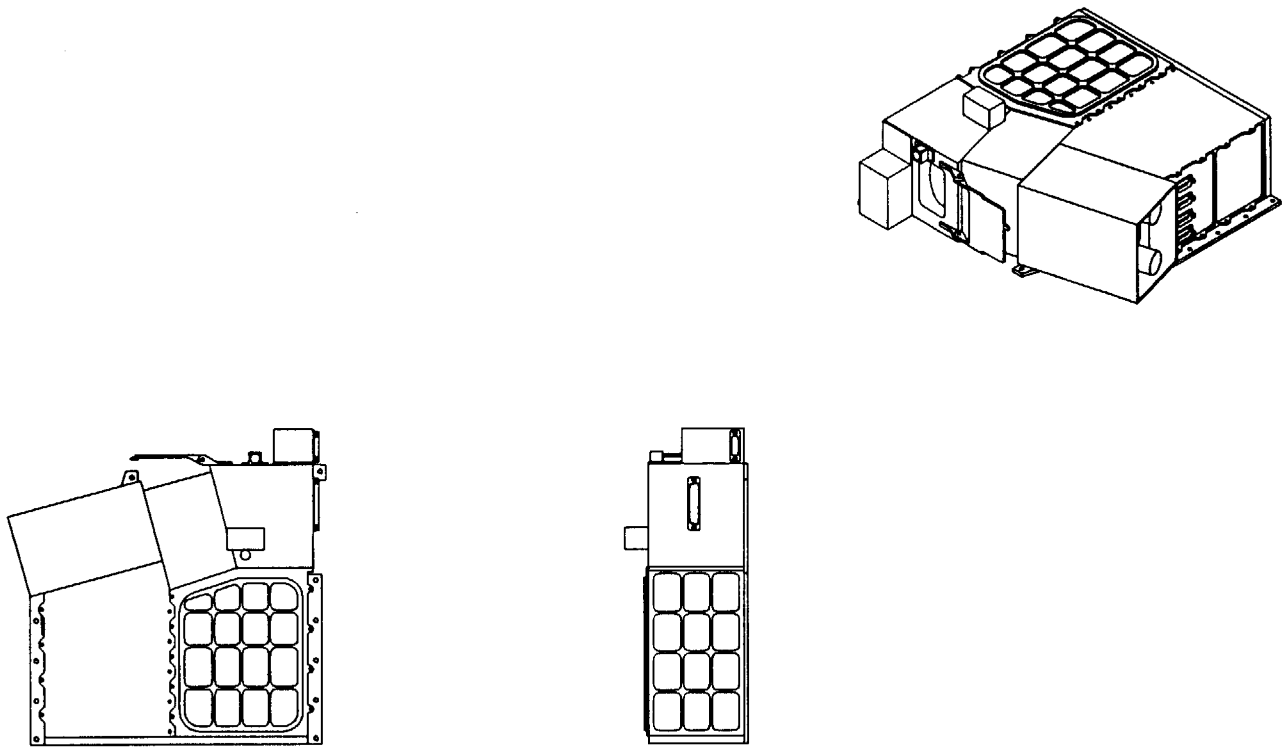
PAYLOAD

FRAME 10
L305581


+X
ULTRAVIOLET COSMIC BACKGROUND SPECTROGRAPH FIELD OF VIEW
-Z
+Y
ZENITH FACE ISO
+X
LINEAR ETALON IMAGING SPECTRAL ARRAY FIELD OF REGARD
HYPER SPECTRAL IMAGER FIELD OF VIEW
+Z
-Y
NADIR FACE ISO
SENSOR ASSY
(22.79)
(57.00 TO S/C IF)
PAYLOAD INSTRUMENTS
REVISED: 01/14/95
J
11982
L305581
FRAME 11
L305581


-Y
HYPER SPECTRAL IMAGER (HSI)
HSI CRYOCOOLER
NARROW FOV STAR TRACKER
WIDE FOV STAR TRACKER
EARTH SENSOR ASSY
+Z
GPS ANTENNA 2 PL
GPS ANTENNA GROUND PLANE (Ø12.0 X .062) 2 PL
LEISA OPTICAL POINTING ASSY
LINEAR ETALON IMAGING SPECTRAL ARRAY (LEISA) MOUNTING BRACKET
LEISA CRYOCOOLER
ULTRAVIOLET COSMIC BACKGROUND (UCB) SPECTROMETER
VIEW LOOKING -X
WIDE FOV STAR TRACKER
NARROW FOV STAR TRACKER
+X
UCB
GPS ANTENNA 2 PL
VIEW LOOKING +Z
HSI CRYOCOOLER RADIATOR
+X
HSI SENSOR ASSY
VIEW LOOKING -Y
HSI SENSOR ASSY
LEISA CRYOCOOLER RADIATOR
+X
LEISA
(22.79)
15°
(67.00 TO S/C IF)
EARTH SENSOR ASSY
VIEW LOOKING -Z
FRAME 12
L305581
6
LINEAR

TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E04-4977		11050-1	11060	[illegible]	SSTI	306600



SOURCE CONTROL DRAWING

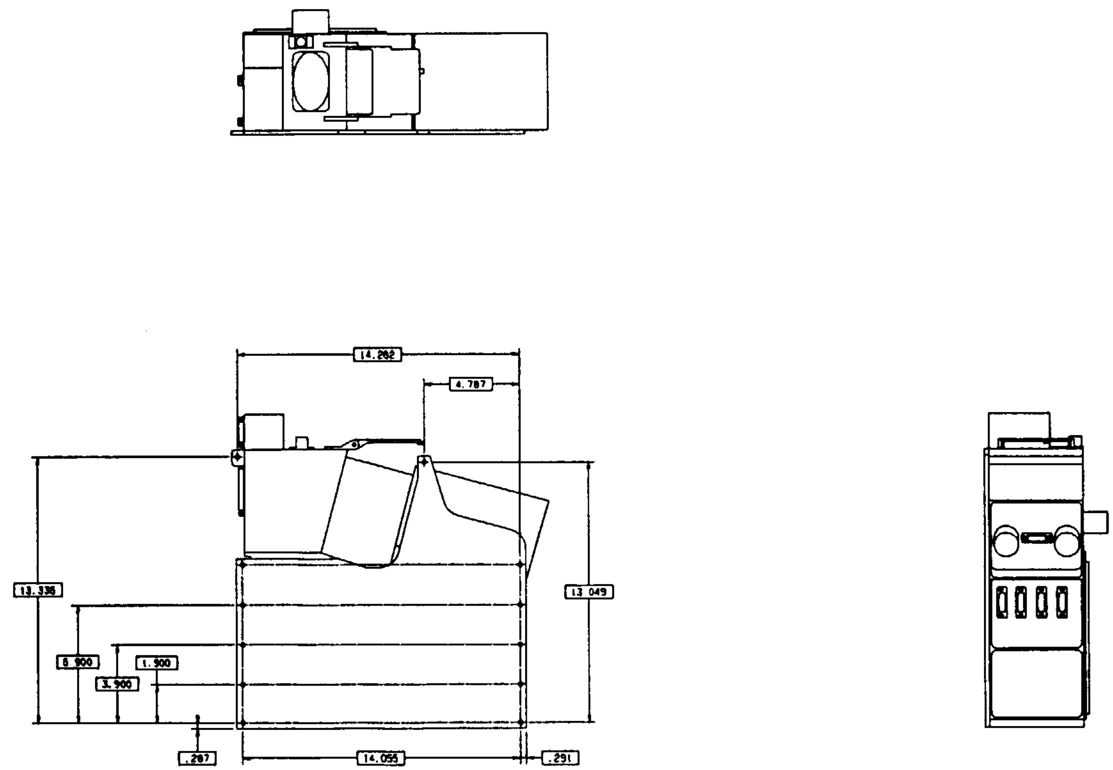
UCB SPECTROMETER

C305602

11982

E04-4977

FRAME 1



NOTES: UNLESS OTHERWISE SPECIFIED

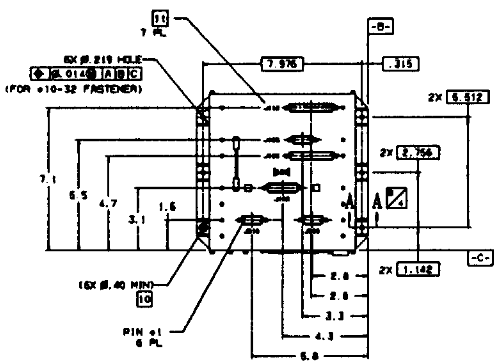
1. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREIN IS APPROVED BY TRW REDONDO BEACH CALIFORNIA FOR USE IN THE APPLICATION(S) SPECIFIED HEREIN. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVIAL BY TRW OR NASA HEADQUARTERS.
2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 24.7 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 7.1 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT EO4-4977.
7. PART IDENT PER EO4-4977. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALLHAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. PROVIDE A Ø.40 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #10 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
11. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

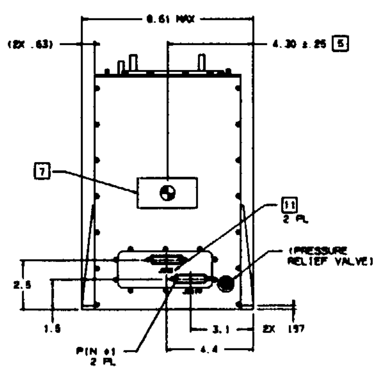
FRAME 2
C305602 | 1

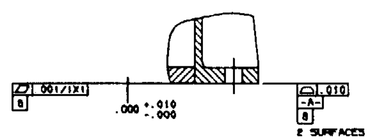
REF DES	CONNECTOR PART •	FUNCTION	TYPE
J010	M24308/4-2	SPACECRAFT INTERFACE	15P
J020	M24308/4-2	SPACECRAFT INTERFACE	15P
J102	M24308/4-3	ADC INPUT	25P
J106	M24308/4-4	HOUSEKEEPING ADC	37P
J108	M24308/2-2	HV CONTROLLER	15S
J112	M24308/2-4	FILTER WHEEL MOTOR CONTROLLER	37S
J001	M24308/4-3	S/C POWER	25P
J05E	M24308/2-3	TEST INTERFACE	25S

CONNECTOR DATA

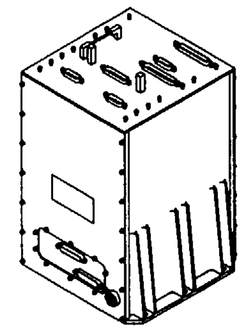
TRW		APPROVED SOURCES OF SUPPLY				APPLICATION	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E04-4976	TBD	11051-1	11051	[illegible]	SSTI	306896



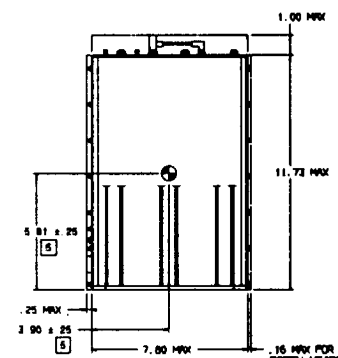




SECTION A-A
BOX FLATNESS
SCALE: 2/1



ISO FOR REFERENCE ONLY



NOTES: UNLESS OTHERWISE SPECIFIED

1. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREIN IS APPROVED BY TRW REDONDO BEACH CALIFORNIA FOR USE IN THE APPLICATION(S) SPECIFIED HEREIN. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVIAL BY TRW OR NASA HEADQUARTERS.
2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 14.6 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 16.0 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E04-4976.
7. PART IDENT PER E04-4976. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALLHAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. PROVIDE A Ø.40 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #10 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
11. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS PER .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

SOURCE CONTROL DRAWING

TRW

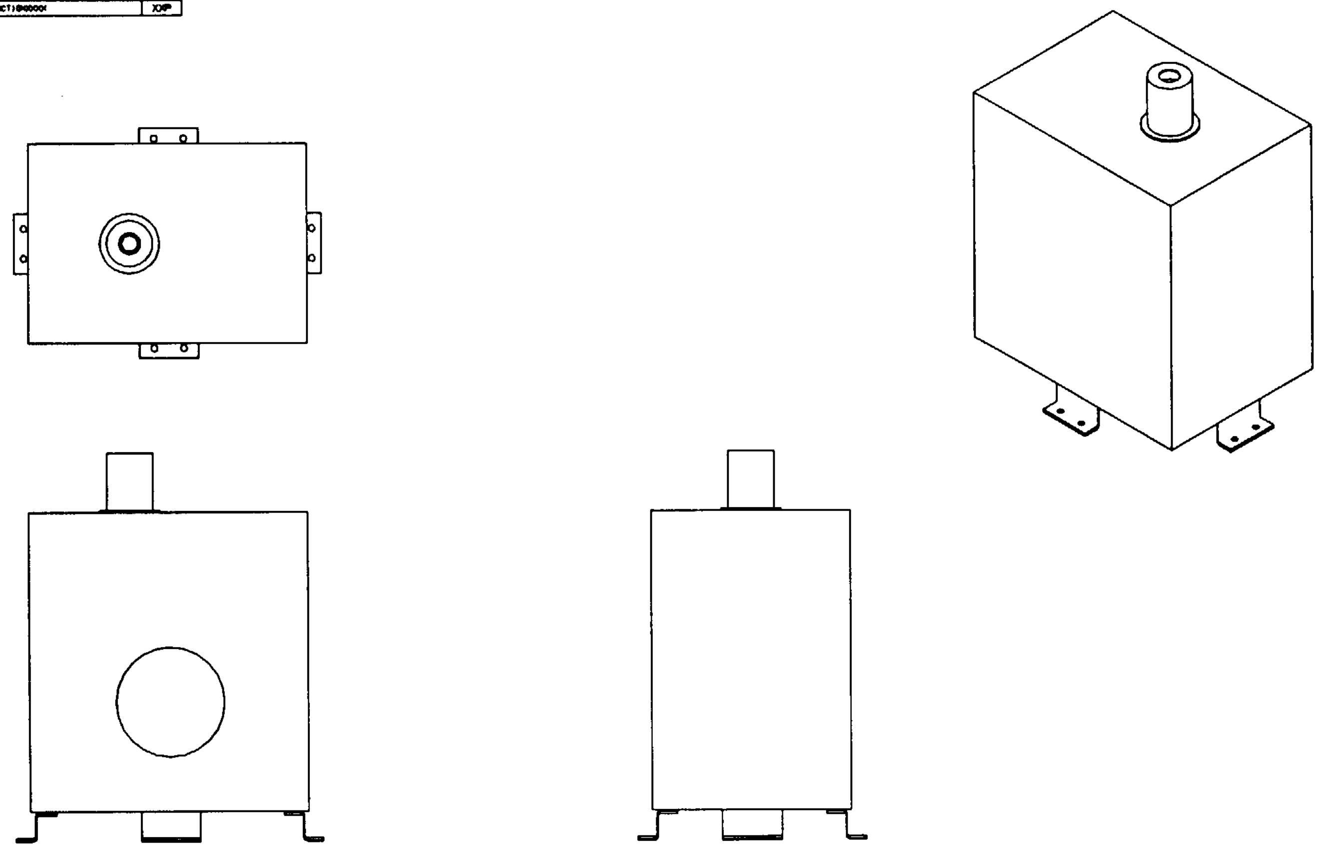
UCB ELECTRONICS BOX

E 11982 C305603

CONNECTOR DATA

REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	CANNON MDM-XXP	XXXXFUNCTIONXXXX	XXP
J2	CANNON MDM-XXP	XXXXFUNCTIONXXXX	XXP
J3	CANNON MDM-XXP	XXXXFUNCTIONXXXX	XXP
J4	CANNON MDM-XXP	XXXXFUNCTIONXXXX	XXP

TRW		APPROVED SOURCES OF SUPPLY				APPLICATION	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E02-0326	TBD	TBD	TBD	NASA/GODDARD SPACE FLIGHT CENTER GREENBELT, MD 20771	SSTI	306696



NOTES: UNLESS OTHERWISE SPECIFIED

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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 5.5 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 7.3 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E02-0326.
7. PART IDENT PER E02-0326. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALLHAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. PROVIDE A Ø 30 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #6 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
11. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

SOURCE CONTROL DRAWING

NASW-4946

TRW

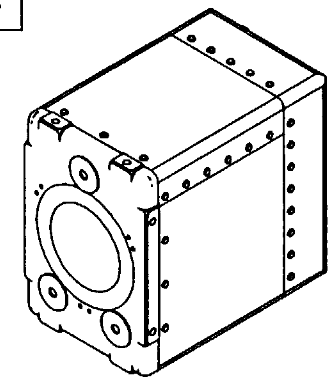
LINEAR ETALON IMAGING SPECTRAL ARRAY (LEISA)

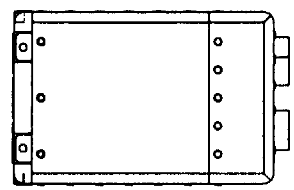
E 11982 C305605

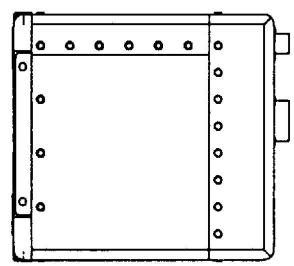
SSTI 306696 E02-0326

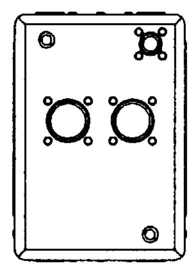
C305605

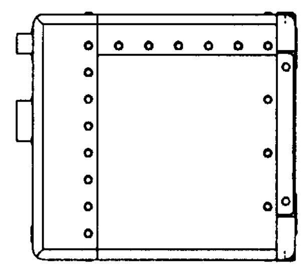
TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	1
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	IF31-016	8F963	TBD	TBD	HUGHES DANBURY OPTICS DANBURY, CT	SST1	305596











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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 7.1 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 11.9 WATTS PEAK.
5. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT IF31-016
7. PART IDENTIFICATION SHALL BE PER IF31-016. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .16 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
11. PROVIDE A ⌀0.35 MINIMUM FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER / TOOL CLEARANCE.

SOURCE CONTROL DRAWING

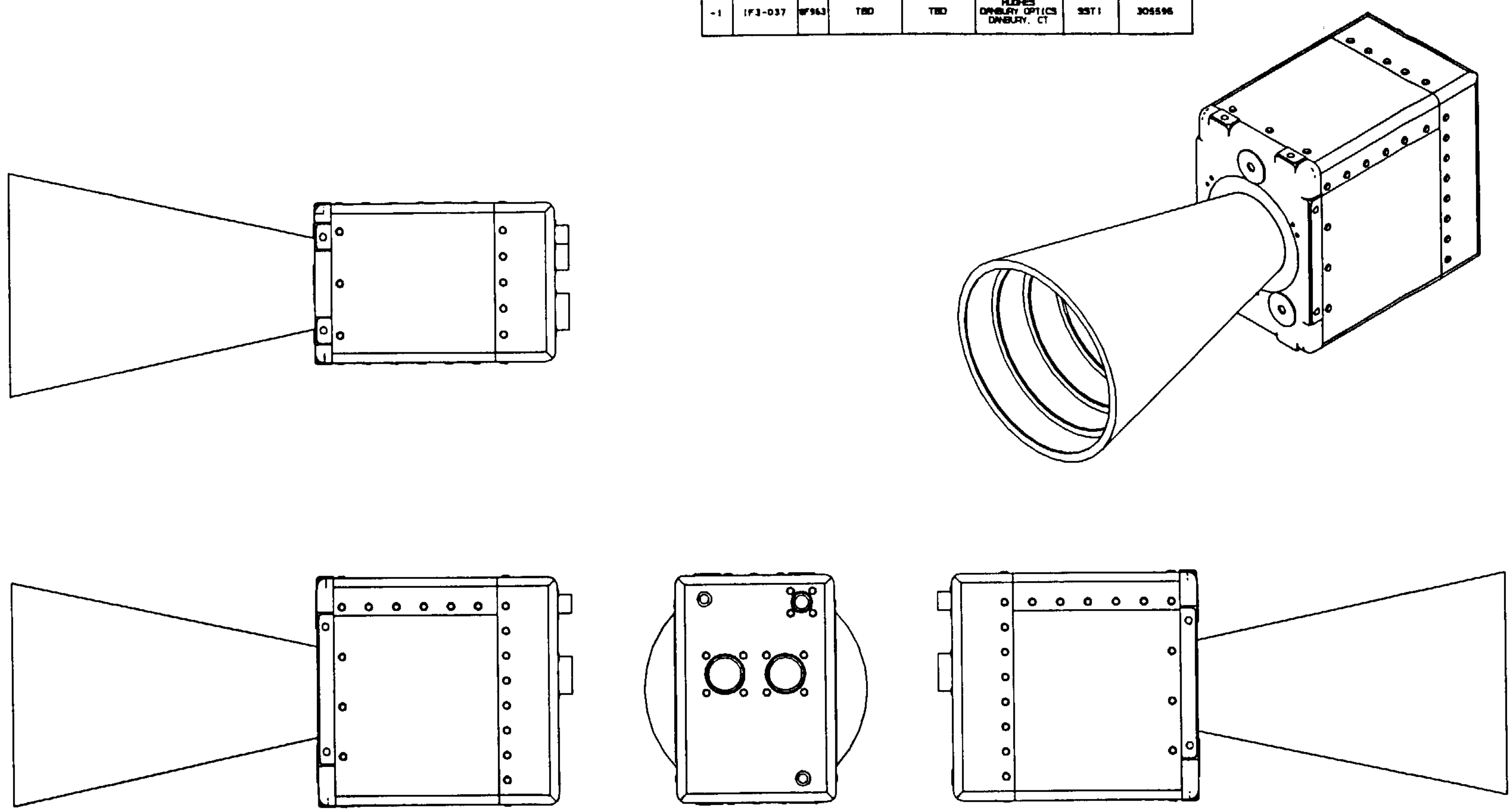
NASW-4945

TRW

WIDE FOV STAR TRACKER

E 11982 C305607

TRW		1 APPROVED SOURCES OF SUPPLY				APPLICATION 1	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	IF3-037	0F963	TBD	TBD	HUGHES DANBURY OPTICS DANBURY, CT	SSTI	305596



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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 7.5 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 11.9 WATTS PEAK.
6. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT IF3-037.
7. PART IDENTIFICATION SHALL BE PER IF3-037. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
11. PROVIDE A ⌀0.35 MINIMUM FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER / TOOL CLEARANCE.

SOURCE CONTROL DRAWING

NASW-4945
M. GEORGES

TRW

NARROW FOV
STAR TRACKER

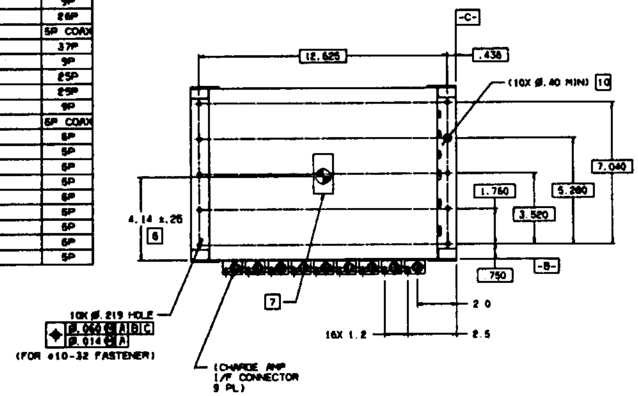
11982 C305608

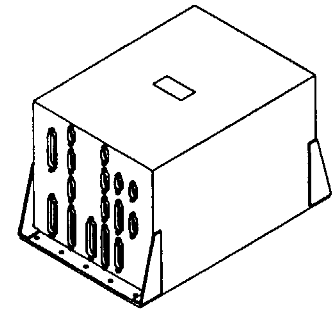
SSTI 305596 IF3-037

CATIA

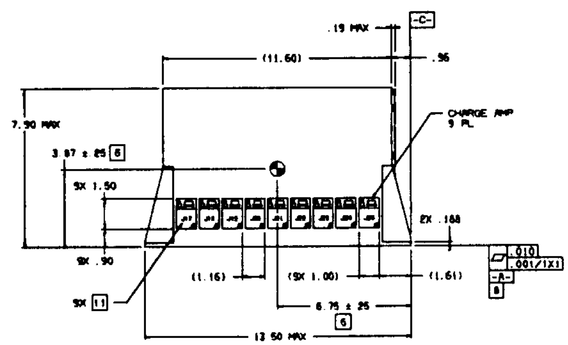
CONNECTOR DATA			
REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	XXXCANNON DXXX	XXXFUNCTIONXXX	60P
J2	XXXCANNON DXXX	XXXFUNCTIONXXX	78P
J3	XXXCANNON DXXX	XXXFUNCTIONXXX	9P
J4	XXXCANNON DXXX	XXXFUNCTIONXXX	26P
J5	XXXCANNON DXXX	XXXFUNCTIONXXX	5P COAX
J6	XXXCANNON DXXX	XXXFUNCTIONXXX	37P
J7	XXXCANNON DXXX	XXXFUNCTIONXXX	78P
J8	XXXCANNON DXXX	XXXFUNCTIONXXX	9P
J9	XXXCANNON DXXX	XXXFUNCTIONXXX	26P
J10	XXXCANNON DXXX	XXXFUNCTIONXXX	5P COAX
J11	XXXCANNON DXXX	XXXFUNCTIONXXX	37P
J12	XXXCANNON DXXX	XXXFUNCTIONXXX	9P
J13	XXXCANNON DXXX	XXXFUNCTIONXXX	25P
J14	XXXCANNON DXXX	XXXFUNCTIONXXX	25P
J14	XXXCANNON DXXX	XXXFUNCTIONXXX	9P
J15	XXXCANNON DXXX	XXXFUNCTIONXXX	5P COAX
J17	TBD	XXXFUNCTIONXXX	5P
J18	TBD	XXXFUNCTIONXXX	5P
J19	TBD	XXXFUNCTIONXXX	5P
J20	TBD	XXXFUNCTIONXXX	5P
J21	TBD	XXXFUNCTIONXXX	5P
J22	TBD	XXXFUNCTIONXXX	5P
J23	TBD	XXXFUNCTIONXXX	5P
J24	TBD	XXXFUNCTIONXXX	5P
J25	TBD	XXXFUNCTIONXXX	5P

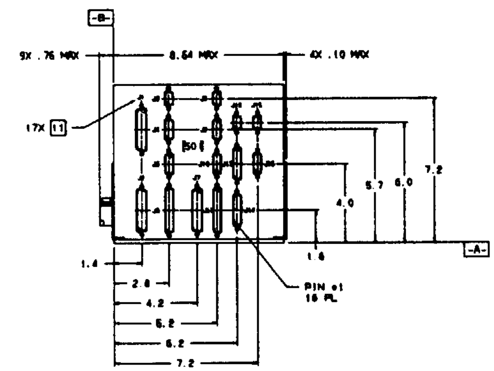
TRW	1	APPROVED SOURCES OF SUPPLY				APPLICATION	1
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	IF31-009	XXXXX	XXPART NOXX	XXDWGXX	[illegible]	SSTI	306696





ISO FOR REFERENCE ONLY





SOURCE CONTROL DRAWING

NOTES: UNLESS OTHERWISE SPECIFIED

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3. UNIT WEIGHT SHALL NOT EXCEED 21.4 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 11.6 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT IF31-009.
7. PART IDENT PER IF31-009. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. PROVIDE A Ø.40 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #10 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
11. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

TRW

GODDARD ELECTRONICS MODULE

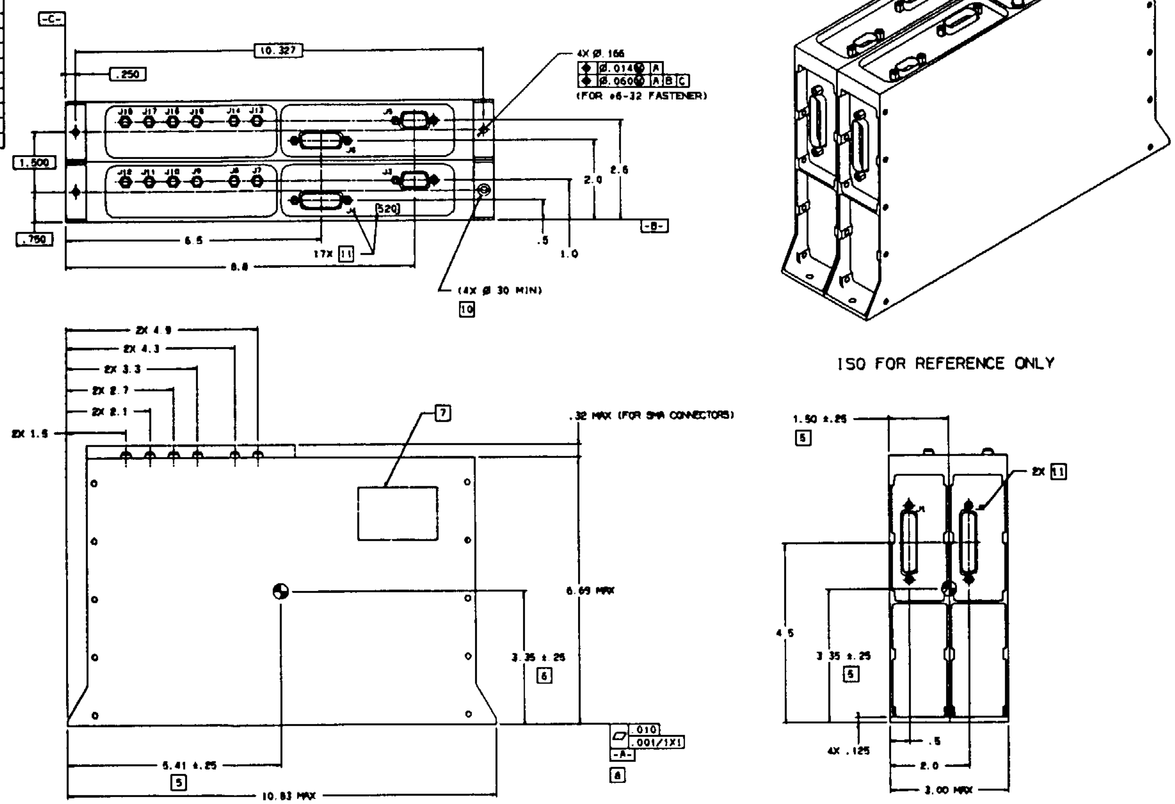
E 11982 C305609

SSTI 306696 IF31-009

TRW			APPROVED SOURCES OF SUPPLY			APPLICATION	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E031-013	XXXXX	TBD	TBD	TBD	SSTI	306898

CONNECTOR DATA

REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	MIL-C-TBD	XXXXFUNCTIONXXXX	25P
J2	MIL-C-TBD	XXXXFUNCTIONXXXX	25P
J3	MIL-C-TBD	XXXXFUNCTIONXXXX	9P
J4	MIL-C-TBD	XXXXFUNCTIONXXXX	15P
J5	MIL-C-TBD	XXXXFUNCTIONXXXX	9P
J6	MIL-C-TBD	XXXXFUNCTIONXXXX	15P
J7	MIL-C-TBD	XXXXFUNCTIONXXXX	COAX
J8	MIL-C-TBD	XXXXFUNCTIONXXXX	COAX
J9	MIL-C-TBD	XXXXFUNCTIONXXXX	COAX
J10	MIL-C-TBD	XXXXFUNCTIONXXXX	COAX
J11	MIL-C-TBD	XXXXFUNCTIONXXXX	COAX
J12	MIL-C-TBD	XXXXFUNCTIONXXXX	COAX
J13	MIL-C-TBD	XXXXFUNCTIONXXXX	COAX
J14	MIL-C-TBD	XXXXFUNCTIONXXXX	COAX
J15	MIL-C-TBD	XXXXFUNCTIONXXXX	COAX
J16	MIL-C-TBD	XXXXFUNCTIONXXXX	COAX
J17	MIL-C-TBD	XXXXFUNCTIONXXXX	COAX
J18	MIL-C-TBD	XXXXFUNCTIONXXXX	COAX



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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 6.8 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED XX.X WATTS PEAK.
5. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E031-013.
7. PART IDENT PER E031-013. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. PROVIDE A Ø.30 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #6 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
11. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

SOURCE CONTROL DRAWING

TRW

GPS RECEIVER

NASW-4946

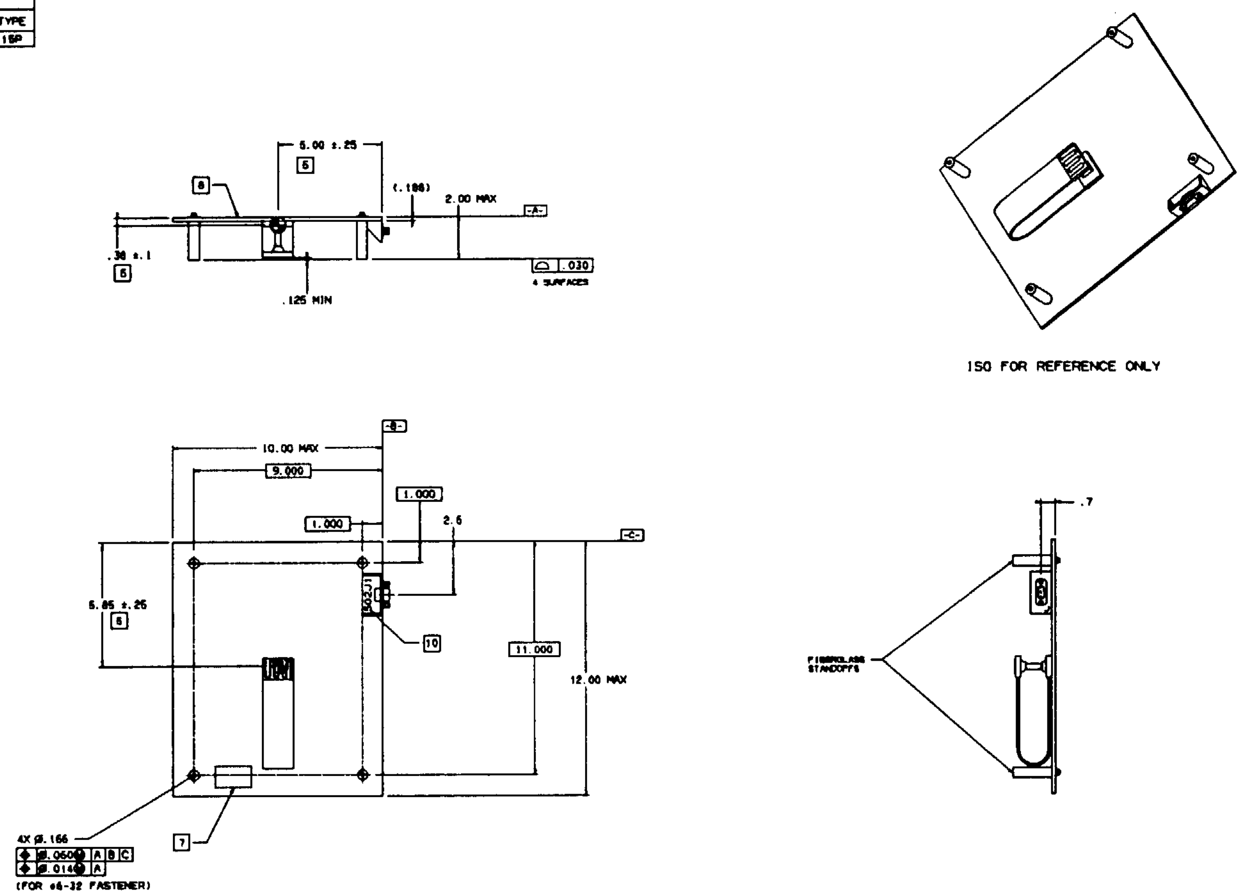
E 11982 C305610

SSTI E031-013

TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	EQ31-007	XXXXX	TBD	TBD	NASA GSFC CODE 722 GREENBELT, MD	SSTI	306696

CONNECTOR DATA

REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	2A014-XXXV-001	TBD	15P



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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 3.2 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 1.7 WATT PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT EQ31-007.
7. PART IDENTIFICATION SHALL BE PER EQ31-007. LOCATE APPROXIMATELY AS SHOWN.
8. OUTBOARD RADIATOR SURFACE SHALL BE COVERED/COATED WITH EITHER .005 AGFEP TAPE OR Z93 WHITE PAINT.
9. CONNECTOR SHALL BE EQUIPPED WITH A CONNECTOR SAVER AND DUST COVER.
10. MARK APPROPRIATE UNIT DESIGNATOR WITH .18 MIN HIGH CHARACTERS. LOCATE APPROXIMATELY AS SHOWN.

SOURCE CONTROL DRAWING

NAS5-4945

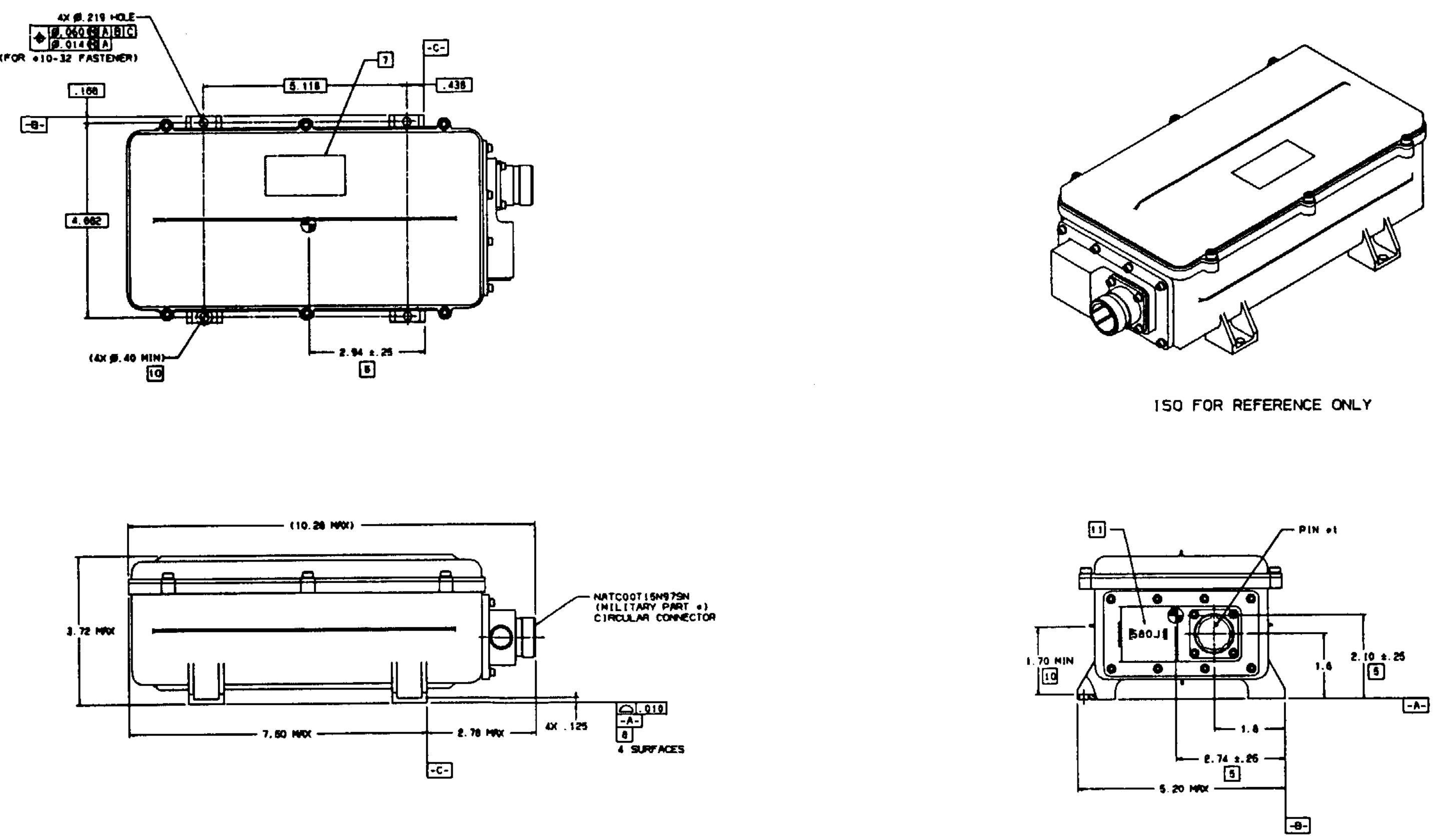
TRW

METAL MATRIX HEAT STRAP

E 11982 C305612

SSTI 306696 EQ31-007

TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	1
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E031-006	21356	GPC-001-XX	GPC-001-XX	[illegible]	SSTI	306696



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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 5.5 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 5.0 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E031-006.
7. PART IDENT PER E031-006. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. PROVIDE A Ø.40 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #10 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO NOTED DIMENSION.
11. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .18 MIN HIGH CHARACTERS. LOCATE APPROXIMATELY AS SHOWN.

SOURCE CONTROL DRAWING

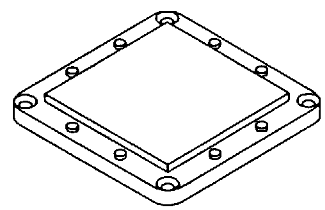
TRW

GAS PROPORTIONAL COUNTER

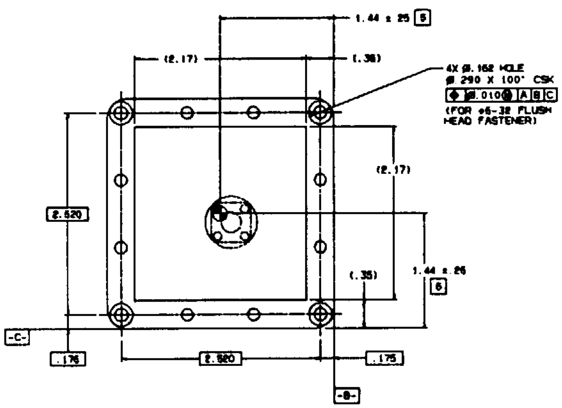
E 11982 C305613

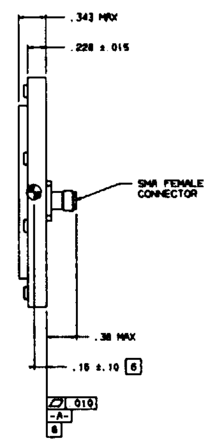
SSTI 306696 E031-006

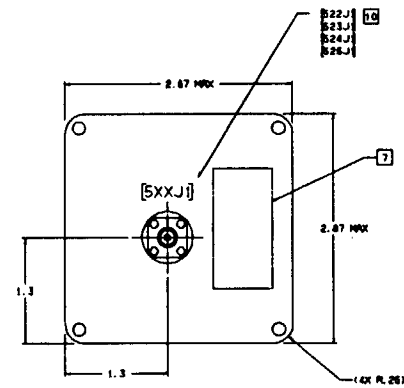
TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	1
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E031-012	0E5R2	301699-1	301699	[illegible]	SSTI	306696 306699



ISO FOR REFERENCE ONLY







NOTES: UNLESS OTHERWISE SPECIFIED

1. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREIN IS APPROVED BY TRW REDONDO BEACH CALIFORNIA FOR USE IN THE APPLICATION(S) SPECIFIED HEREIN. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVIAL BY TRW OR NASA HEADQUARTERS.
2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 0.5 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 0.0 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E031-012.
7. PART IDENT PER E031-012. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTOR SHALL BE EQUIPPED WITH A CONNECTOR SAVER AND DUST COVER.
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUT WITH .10 MIN HIGH CHARACTERS. LOCATE APPROXIMATELY AS SHOWN.

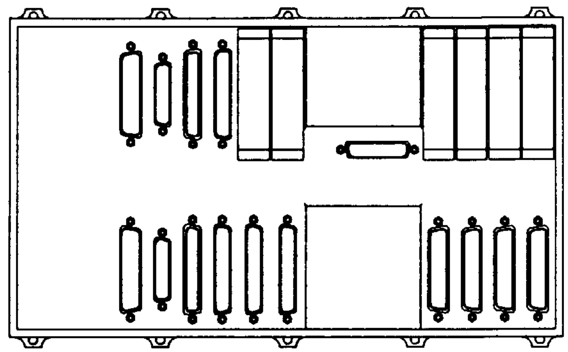
SOURCE CONTROL DRAWING

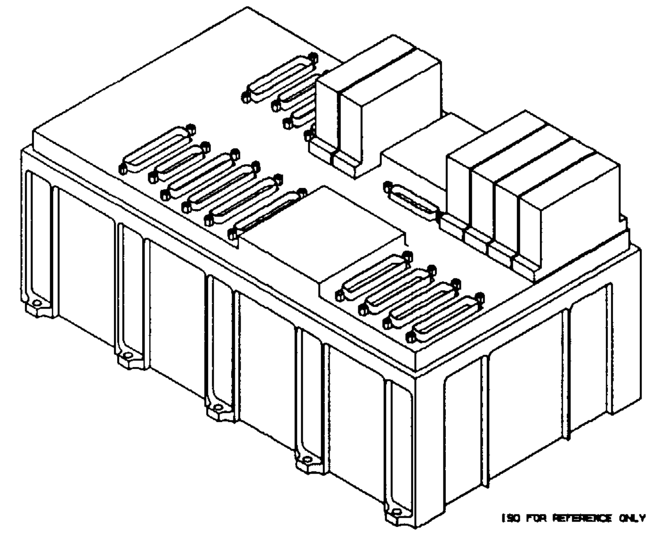
TRW

GPS ANTENNA

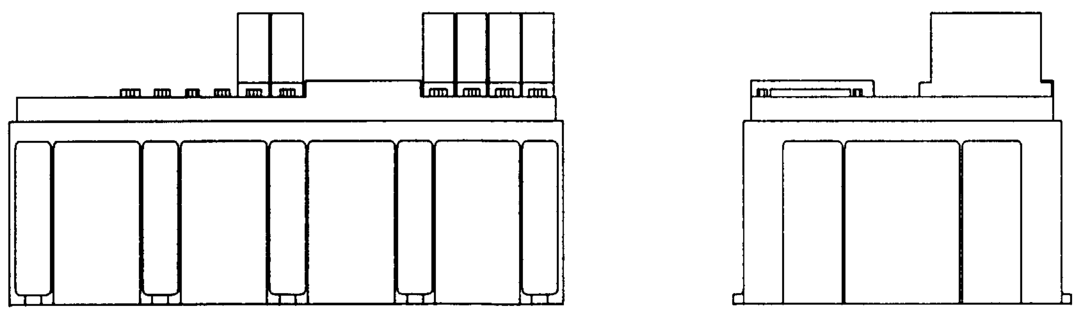
E 11982 C305614

TRW		APPROVED SOURCES OF SUPPLY				APPLICATION	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	EO3-061	12574	AN81433-001 -01	AN81433-001	GULTON DATA SYSTEMS ALBUQUERQUE, NM	SSTI	305597





ISO FOR REFERENCE ONLY



CONNECTOR DATA			
REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	MIL-C-24308/6-2	POWER INPUT	15P
J2	MIL-C-24308/6-14	CPU INTERFACE	62S
J3	MIL-C-24308/6-13	TIMING	44S
J4	MIL-C-24308/6-13	TRANSPONDER INTERFACE	44P
J5	MIL-C-24308/6-2	OSE INTERFACE	15S
J6	MIL-C-24308/6-12	SPACECRAFT ADDRESS	26P
J7	MIL-C-24308/6-12	SADE INTERFACE	26S
J8	MIL-C-24308/6-12	TACH FEEDBACK INPUT	26P
J9	MIL-C-24308/6-16	SERIAL INTERFACE	78P
J10	MIL-C-24308/6-15	BILEVEL INTERFACE	78S
J11	MIL-C-24308/6-15	BILEVEL INTERFACE	78S
J12	MIL-C-24308/6-13	GYRO INPUT	44S
J13	MIL-C-24308/6-12	REACTION WHEEL OUTPUT	26S
J14	MIL-C-24308/6-16	ANALOG INPUT	78P
J15	MIL-C-24308/6-15	ANALOG INPUT	78P
J16	MIL-C-24308/6-15	ANALOG INPUT	78P
J17	MIL-C-24308/6-16	ANALOG INPUT	78P

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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 20.5 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 12.4 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT EO3-061.
7. PART IDENTIFICATION SHALL BE PER EO3-016 LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .16 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

SOURCE CONTROL DRAWING

NASW-4945

TRW

POWER CONTROL UNIT

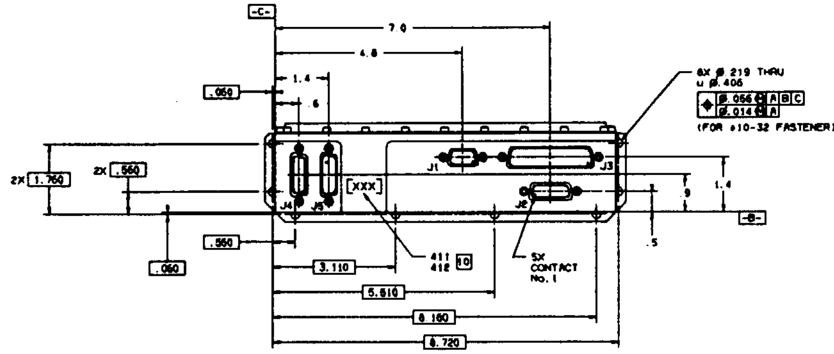
E 11982 C305615

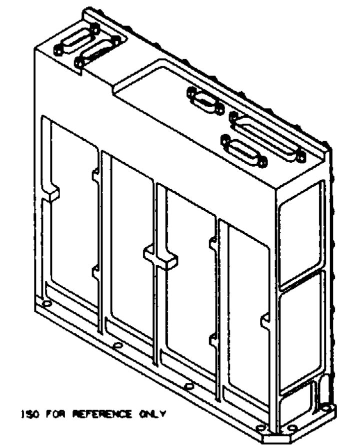
SSTI 305597 EO3-061

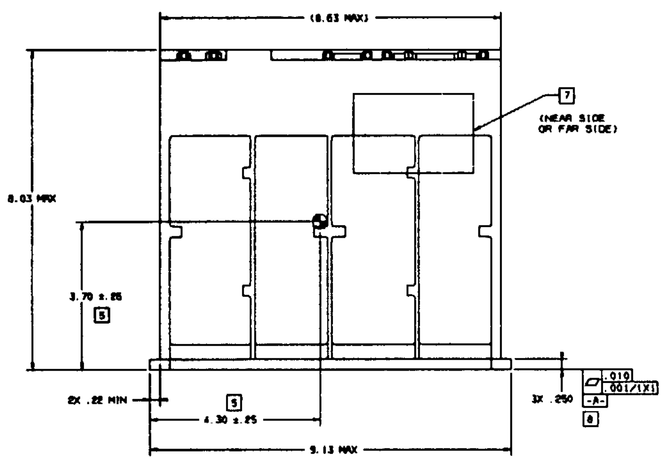
CONNECTOR DATA

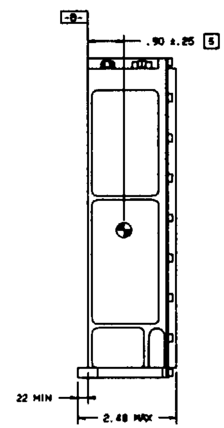
REF DES	CONNECTOR PART #	FUNCTION	DESCRIPTION
J1	MIL-C-18271-1	SOLAR ARRAY INPUT	9 CONTACT PIN
J2	MIL-C-18270-2	ARM 1 OUTPUT	15 CONTACT SOCKET
J3	MIL-C-18271-5	COMMAND AND CONTROL I/F	78 CONTACT PIN
J4	MIL-C-18270-2	ARM 2 OUTPUT	15 CONTACT SOCKET
J5	MIL-C-18271-2	SAR BYPASS	26 CONTACT PIN

TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	1
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E03-059	12674	AN81432-001 -01	AN81432-001	GULTON DATA SYSTEMS ALBUQUERQUE NM	SSTI	305597









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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 5.5 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 4.3 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E03-059.
7. PART IDENTIFICATION SHALL BE PER E03-059 LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN 80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPED WITH CONNECTOR SAVERS AND DUST COVERS
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

SOURCE CONTROL DRAWING

TRW

SOLAR ARRAY REGULATOR

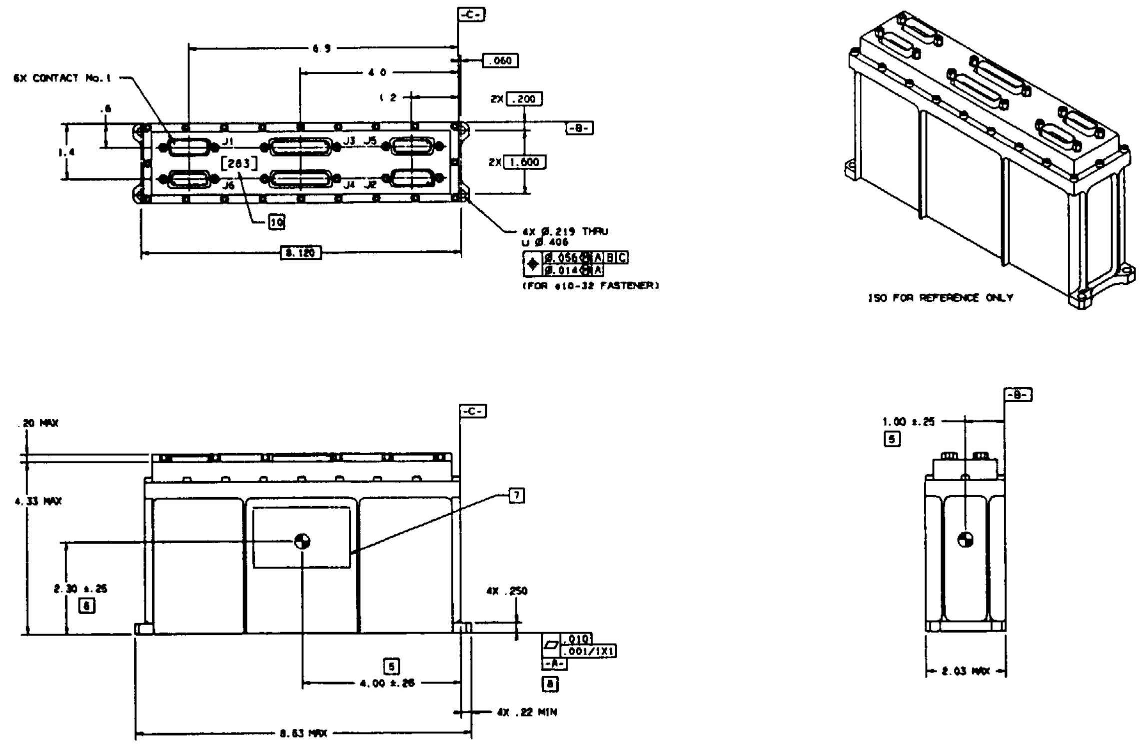
E 11982 C305616

SSTI 305597 E03-059

NASW-4945

CONNECTOR DATA			
REF DES	CONNECTOR PART #	FUNCTION	DESCRIPTION
J1	MIL-C-24308/8-2	POWER INPUT A	15 CONTACT PIN
J2	MIL-C-24308/8-2	POWER INPUT B	15 CONTACT PIN
J3	MIL-C-24308/6-3	DEPLOY DEVISE I/F A	26 CONTACT SOCKET
J4	MIL-C-24308/6-3	DEPLOY DEVISE I/F B	25 CONTACT SOCKET
J5	MIL-C-24308/6-2	COMMAND & CONTROL I/F A	15 CONTACT SOCKET
J6	MIL-C-24308/6-2	COMMAND & CONTROL I/F B	15 CONTACT SOCKET

TRW		APPROVED SOURCES OF SUPPLY				APPLICATION	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E02-0229	12574	AN81435-001 -01	AN81435-001	GULTON DATA SYSTEMS ALBUQUERQUE, NM	SSTI	305597



NOTES: UNLESS OTHERWISE SPECIFIED

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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 2.6 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 0.5 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E02-0229.
7. PART IDENTIFICATION SHALL BE PER E02-0229. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

SOURCE CONTROL DRAWING

TRW

DEPLOYMENT DEVICE CONTROLLER

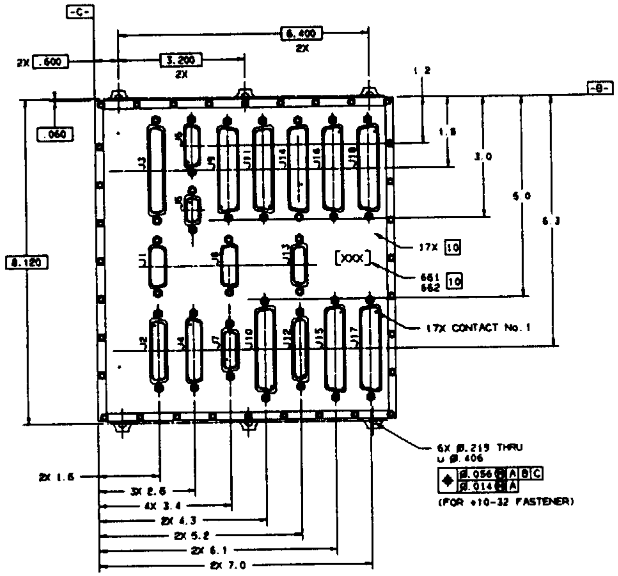
NAS5-4945

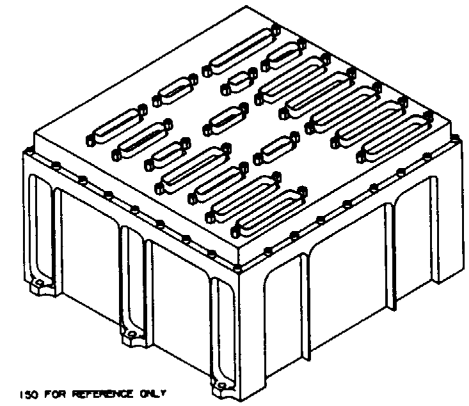
E 11982 C305617

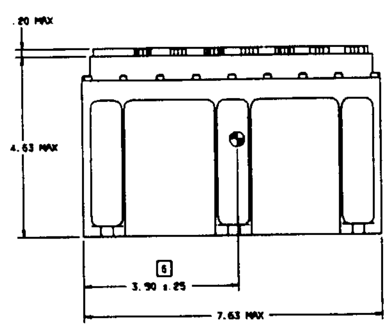
TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	1
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E029-010	12574	AN81433-001 -01	AN81433-001	ULTON DATA SYSTEMS ALBUQUERQUE, NM	SSTI	305597

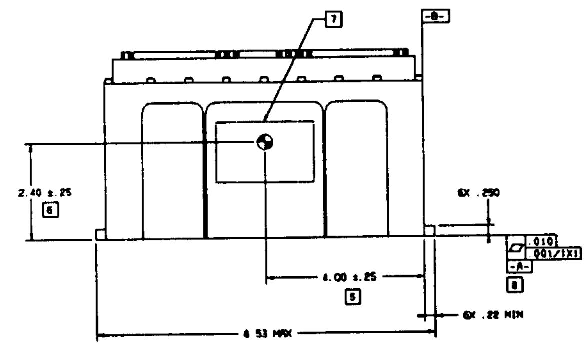
CONNECTOR DATA

REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	MIL-C-24308/8-2	POWER INPUT	15P
J2	MIL-C-24308/6-14	CPU INTERFACE	62S
J3	MIL-C-24308/6-13	TIMING	44S
J4	MIL-C-24308/8-13	TRANSPONDER INTERFACE	44P
J5	MIL-C-24308/6-2	GSE INTERFACE	15S
J6	MIL-C-24308/8-12	SPACECRAFT ADDRESS	26P
J7	MIL-C-24308/6-12	SADE INTERFACE	26S
J8	MIL-C-24308/8-12	TACH FEEDBACK INPUT	26P
J9	MIL-C-24308/8-15	SERIAL INTERFACE	78P
J10	MIL-C-24308/6-15	BILEVEL INTERFACE	78S
J11	MIL-C-24308/6-15	BILEVEL INTERFACE	78S
J12	MIL-C-24308/6-13	GYRO INPUT	44S
J13	MIL-C-24308/6-12	REACTION WHEEL OUTPUT	26S
J14	MIL-C-24308/8-15	ANALOG INPUT	78P
J15	MIL-C-24308/8-15	ANALOG INPUT	78P
J16	MIL-C-24308/8-15	ANALOG INPUT	78P
J17	MIL-C-24308/8-15	ANALOG INPUT	78P









NOTES: UNLESS OTHERWISE SPECIFIED

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3. UNIT WEIGHT SHALL NOT EXCEED 5.6 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 9.6 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E029-010.
7. PART IDENTIFICATION SHALL BE PER E029-010. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .10 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

SOURCE CONTROL DRAWING

NASW-4945

TRW

DATA INTERFACE UNIT

E 11982 C305618

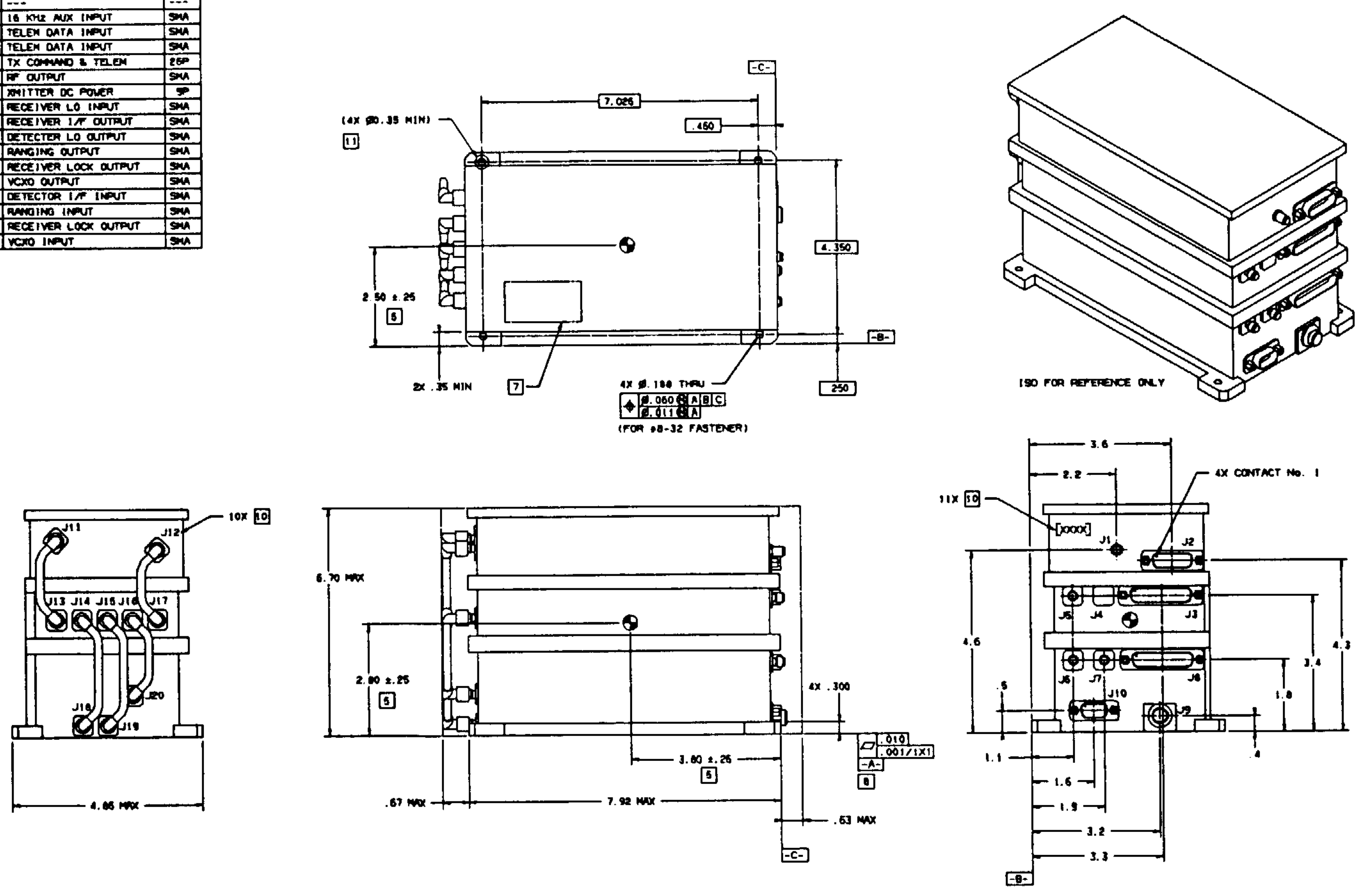
SSTI 305597 E029-010

C305618

TRW			APPROVED SOURCES OF SUPPLY			APPLICATION	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	EOX-XXXX	XXXXX	TWB11005701	TWB11005701	LORAL, INC SAN DIEGO, CA	SSTI	305597

CONNECTOR DATA

REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	2272092-12	RF INPUT	SMA
J2	16250085-2	RECEIVER, DC POWER	15P
J3	16250085-3	CMD DATA, CLK / RX TLM	25P
J4	---	---	---
J5	M39012/60	16 KHz AUX INPUT	SMA
J6	M39012/60	TELEM DATA INPUT	SMA
J7	M39012/60	TELEM DATA INPUT	SMA
J8	16250085-3	TX COMMAND & TELEM	25P
J9	24250013-1	RF OUTPUT	SMA
J10	16250085-1	XMITTER DC POWER	9P
J11	M39012/60	RECEIVER LO INPUT	SMA
J12	M39012/60	RECEIVER I/F OUTPUT	SMA
J13	M39012/60	DETECTER LO OUTPUT	SMA
J14	M39012/60	RANGING OUTPUT	SMA
J15	M39012/60	RECEIVER LOCK OUTPUT	SMA
J16	M39012/60	VCXO OUTPUT	SMA
J17	M39012/60	DETECTOR I/F INPUT	SMA
J18	M39012/60	RANGING INPUT	SMA
J19	M39012/60	RECEIVER LOCK OUTPUT	SMA
J20	M39012/60	VCXO INPUT	SMA



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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 9.0 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 24.1 WATTS PEAK.
5. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT EOX-XXXX.
7. PART IDENTIFICATION SHALL BE PER EOX-XXXX. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
11. PROVIDE A ⌀0.35 MINIMUM FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER / TOOL CLEARANCE.

SOURCE CONTROL DRAWING

TRW

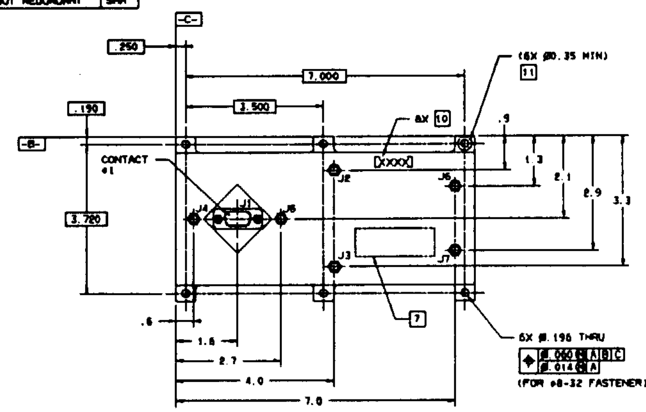
GSTDN TRANSPONDER

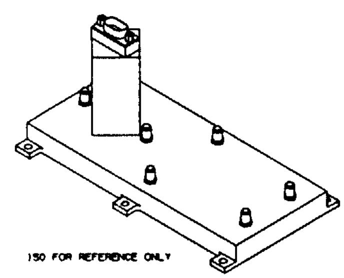
11982 C305619

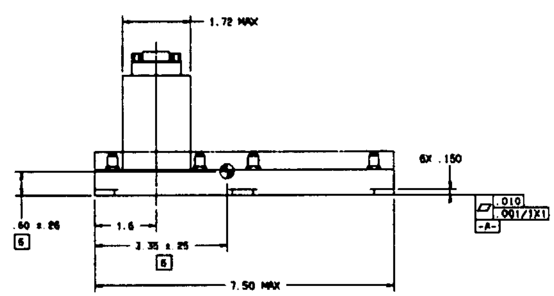
CONNECTOR DATA

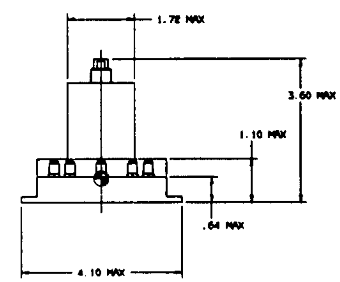
REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	2A014-051V-001	POWER, COMMAND	9P
J2	S223-1186	ANTENNA IN PRIMARY	SMA
J3	S223-1186	ANTENNA IN REDUNDANT	SMA
J4	S223-1186	XPONDER IN PRIMARY	SMA
J5	S223-1186	XPONDER IN REDUNDANT	SMA
J6	S223-1186	XPONDER OUT PRIMARY	SMA
J7	S223-1186	XPONDER OUT REDUNDANT	SMA

TRW		APPROVED SOURCES OF SUPPLY				APPLICATION	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	EDX-XXXX	07180	F355112	D3-6434	SAGE LABS NATICK, MA	SST1	305597









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3. UNIT WEIGHT SHALL NOT EXCEED 1.3 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED TBD WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT EDX-XXXX.
7. PART IDENTIFICATION SHALL BE PER EDX-XXXX. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT SWITCH ASSY AND CONTINUITY SURFACES SHALL BE COATED WITH WITH MIL-C-5541 CLASS 3 CHEM FILM. THE SWITCH ASSY OUTER CASE SHALL BE COATED WITH MIL-C-26074B CLASS 3 GRADE B ELECTROLESS NICKEL.
9. CONNECTORS SHALL BE EQUIPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
11. PROVIDE A Ø0.35 MINIMUM FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER / TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF UNIT.

SOURCE CONTROL DRAWING

NASV-4945

TRW

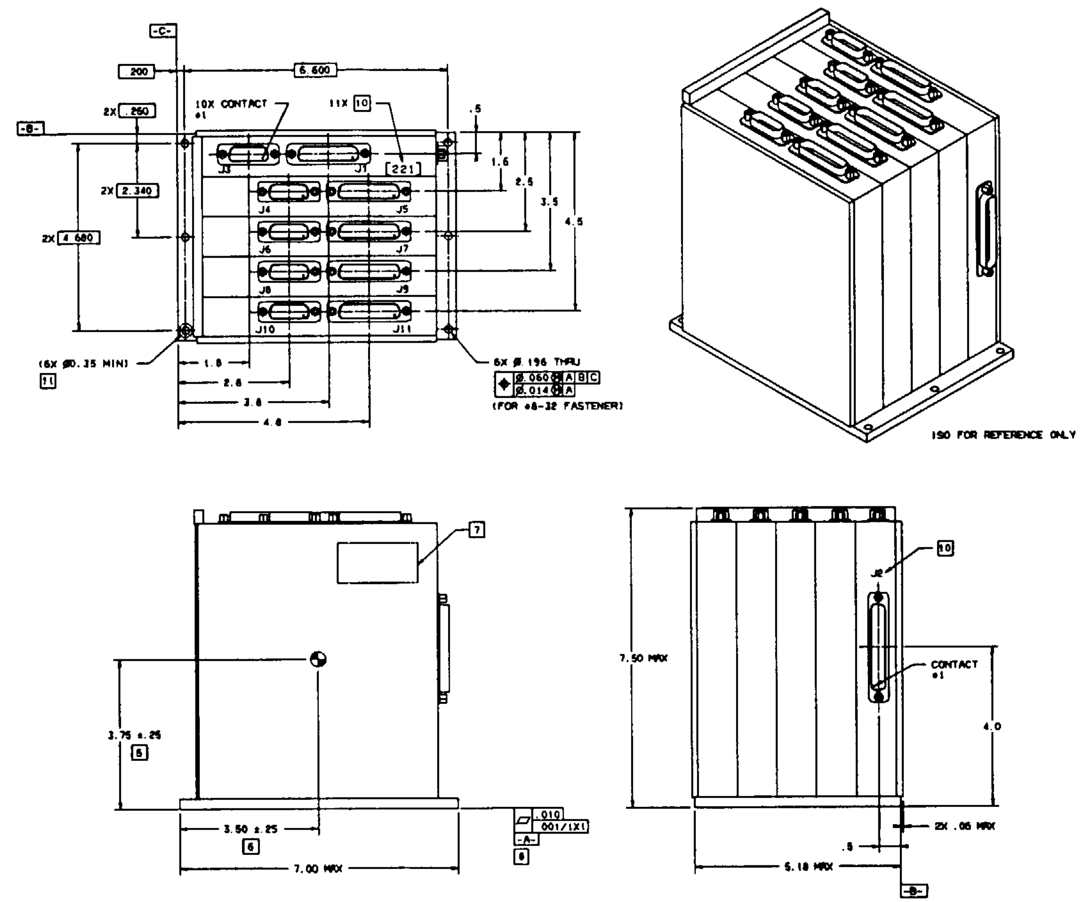
RF ASSEMBLY

E 11982 C305620

SST1 305597 EDX-XXXX

CONNECTOR DATA			
REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	MIL-C-24308/6-3	TDE, COMMAND / TELEM	25P
J2	MIL-C-24308/6-4	TDE, POWER	37P
J3	MIL-C-24308/6-2	TDE, TORQUER I/F	15P
J4	MIL-C-24308/6-2	MDE-A, RWA I/F	15P
J5	MIL-C-24308/6-3	MDE-A, COMMAND / TELEM	25P
J6	MIL-C-24308/6-2	MDE-B, RWA I/F	15P
J7	MIL-C-24308/6-3	MDE-B, COMMAND / TELEM	25P
J8	MIL-C-24308/6-2	MDE-C, RWA I/F	15P
J9	MIL-C-24308/6-3	MDE-C, COMMAND / TELEM	25P
J10	MIL-C-24308/6-2	MDE-D, RWA I/F	15P
J11	MIL-C-24308/6-3	MDE-D, COMMAND / TELEM	25P

TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	1
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E04-4972	26502	43577-1	43577	ITHACO INC ITHACA, NY	SSTI	305597



NOTES: UNLESS OTHERWISE SPECIFIED

1. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREIN IS APPROVED BY TRW REDONDO BEACH CALIFORNIA FOR USE IN THE APPLICATION(S) SPECIFIED HEREIN. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVAL BY TRW OR NASA HEADQUARTERS.
2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 8.1 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 10.7 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E04-4972.
7. PART IDENTIFICATION SHALL BE PER E04-4972. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
11. PROVIDE A Ø0.35 MINIMUM FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER / TOOL CLEARANCE.

SOURCE CONTROL DRAWING

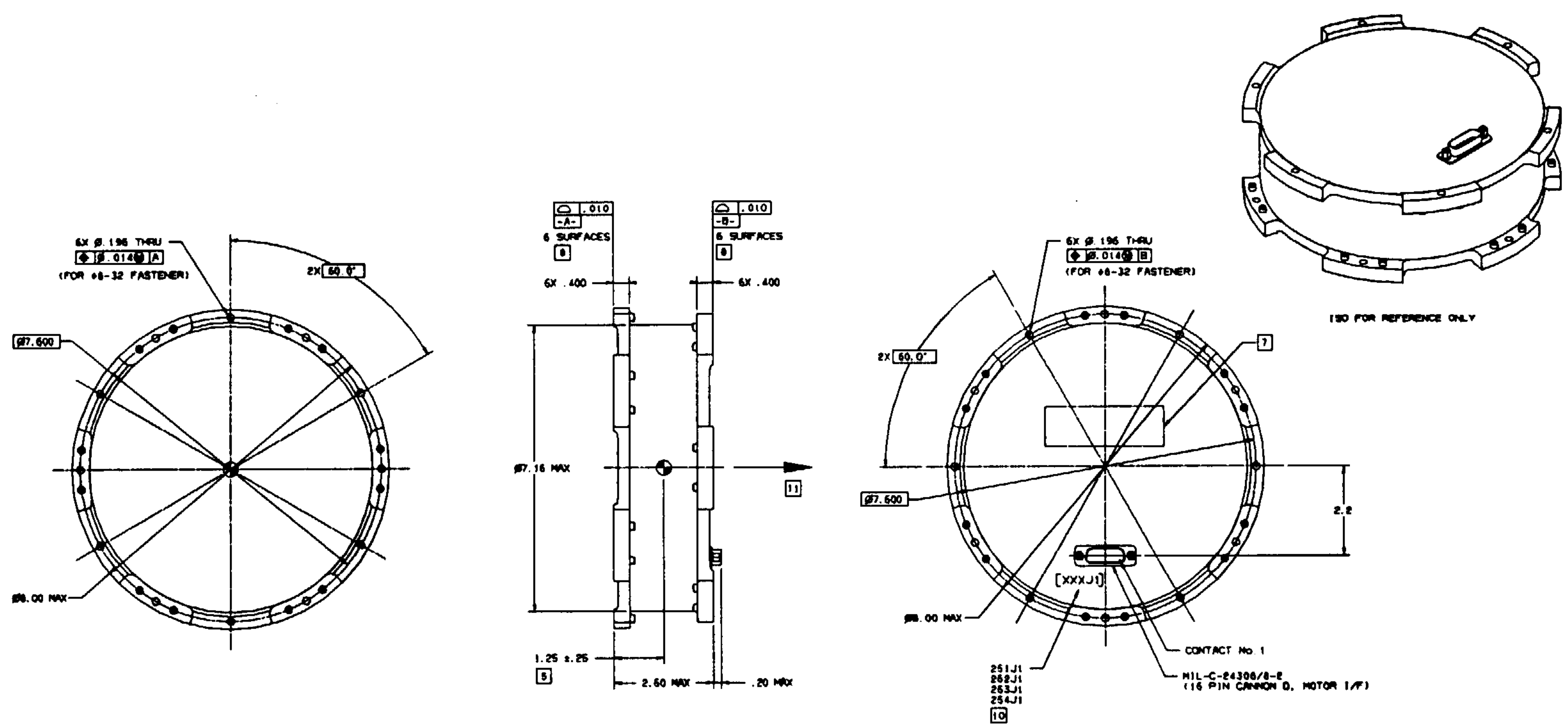
NASV-4945

TRW

CONTROL ELECTRONICS ASSEMBLY

11982 C305621

DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	EO2-0230	26502	43582-1	43582	ITHACO INC ITHACA, NY	SSTI	305597



NOTES: UNLESS OTHERWISE SPECIFIED

1. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREIN IS APPROVED BY TRW REDONDO BEACH CALIFORNIA FOR USE IN THE APPLICATION(S) SPECIFIED HEREIN. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVAL BY TRW OR NASA HEADQUARTERS.
2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 5.5 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 1.9 WATTS PEAK AT 2000 RPM.
5. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT EO2-0230.
7. PART IDENTIFICATION SHALL BE PER EO2-0230. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTOR SHALL BE EQUIPPED WITH CONNECTOR SAVER AND DUST COVER.
10. MARK APPROPRIATE UNIT DESIGNATOR CALLOUT WITH .18 MIN HIGH CHARACTERS. LOCATE APPROXIMATELY AS SHOWN.
11. ARROW DEFINES MOMENTUM AND TORQUE VECTOR ORIENTATION.

SOURCE CONTROL DRAWING

TRW

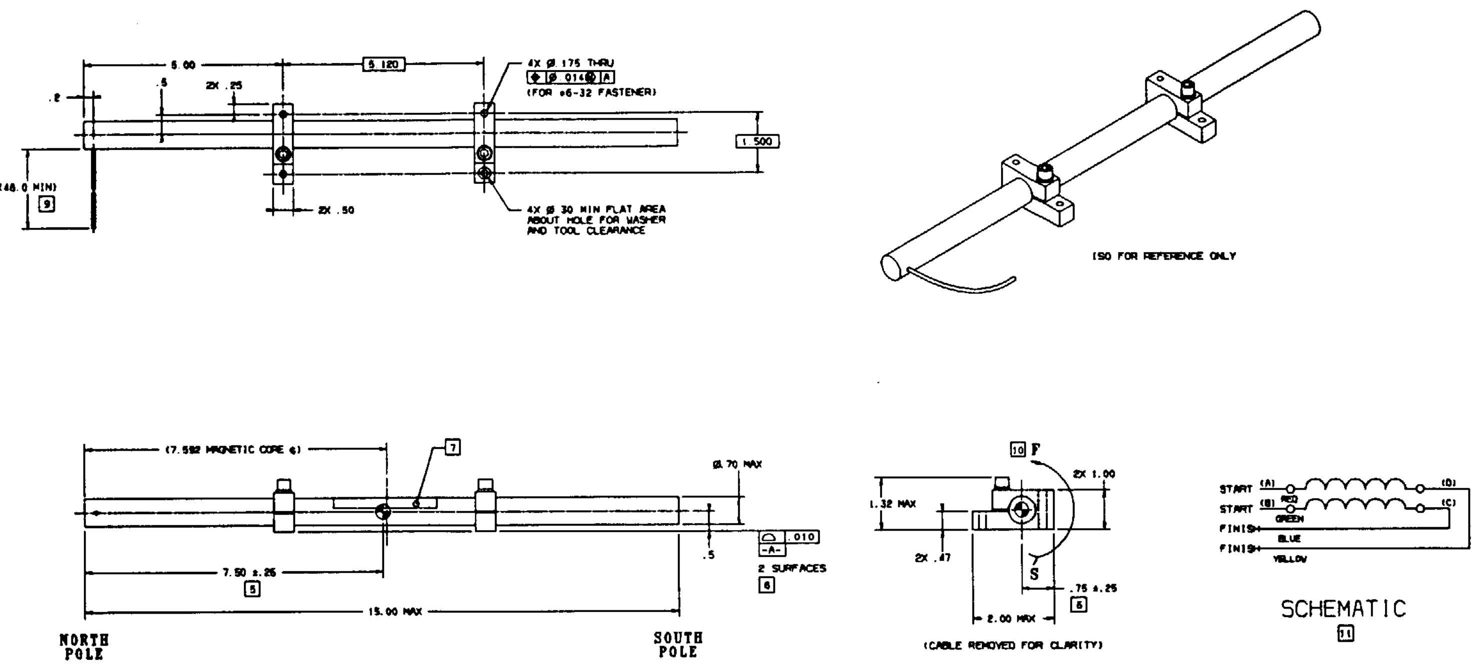
REACTION WHEEL ASSEMBLY

E 11982 C305622

NASW-4945

SSTI 305597 EO2-0230

TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	1
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E02-0321	26602	823326-01	823326-01	ITHACO INC. 735 W. CLINTON ST. ITHACA, N.Y. 14851	SSTI	306897



NOTES: UNLESS OTHERWISE SPECIFIED

1. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREIN IS APPROVED BY TRW REDONDO BEACH CALIFORNIA FOR USE IN THE APPLICATION(S) SPECIFIED HEREIN. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVIAL BY TRW OR NASA HEADQUARTERS.
2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 1.0 POUNDS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 0.67 WATTS PEAK.
5. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E02-0321.
7. PART IDENT SHALL BE PER E02-0321, LOCATE APPROXIMATELY AS SHOWN.
8. ALL SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. MINIMUM LENGTH FOR WIRES IS 48.0 INCHES. CABLE CONSISTS OF FOUR #24 AWG STRANDED TEFSEL INSULATED WIRES. SEE SCHEMATIC FOR COLOR CODING.
10. DIRECTION OF WINDING.
11. CURRENT FLOWING FROM D TO A OR C TO B PRODUCES A NORTH POLE AT THE CABLE END.

SOURCE CONTROL DRAWING

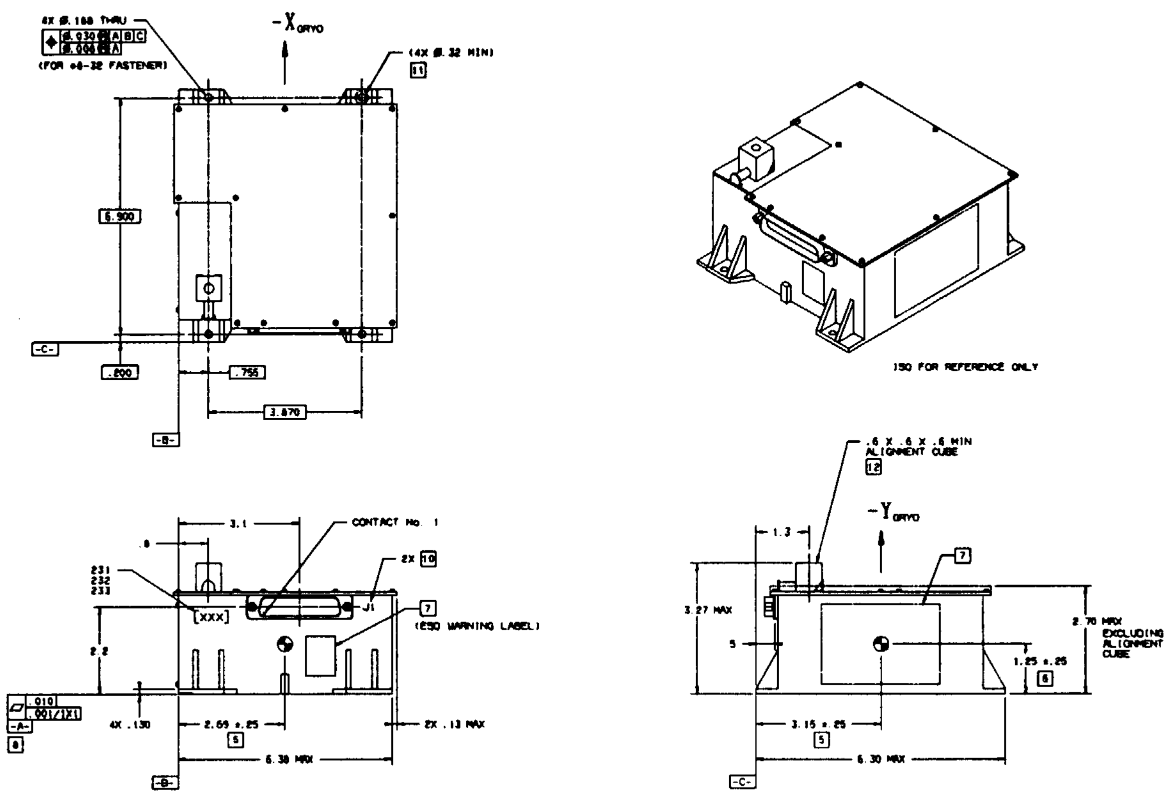
TRW

MAGNETIC TORQUER

11982 C305623

CONNECTOR DATA			
REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	MIL-C-24308/8-5	POWER, SIGNAL, TEST	50P

TRW		APPROVED SOURCES OF SUPPLY 1				APPLICATION 1	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E01-095	36818	K131A014-01	K131A014-01	KEARFOTT GUIDANCE WAYNE, NJ	SSTI	305697



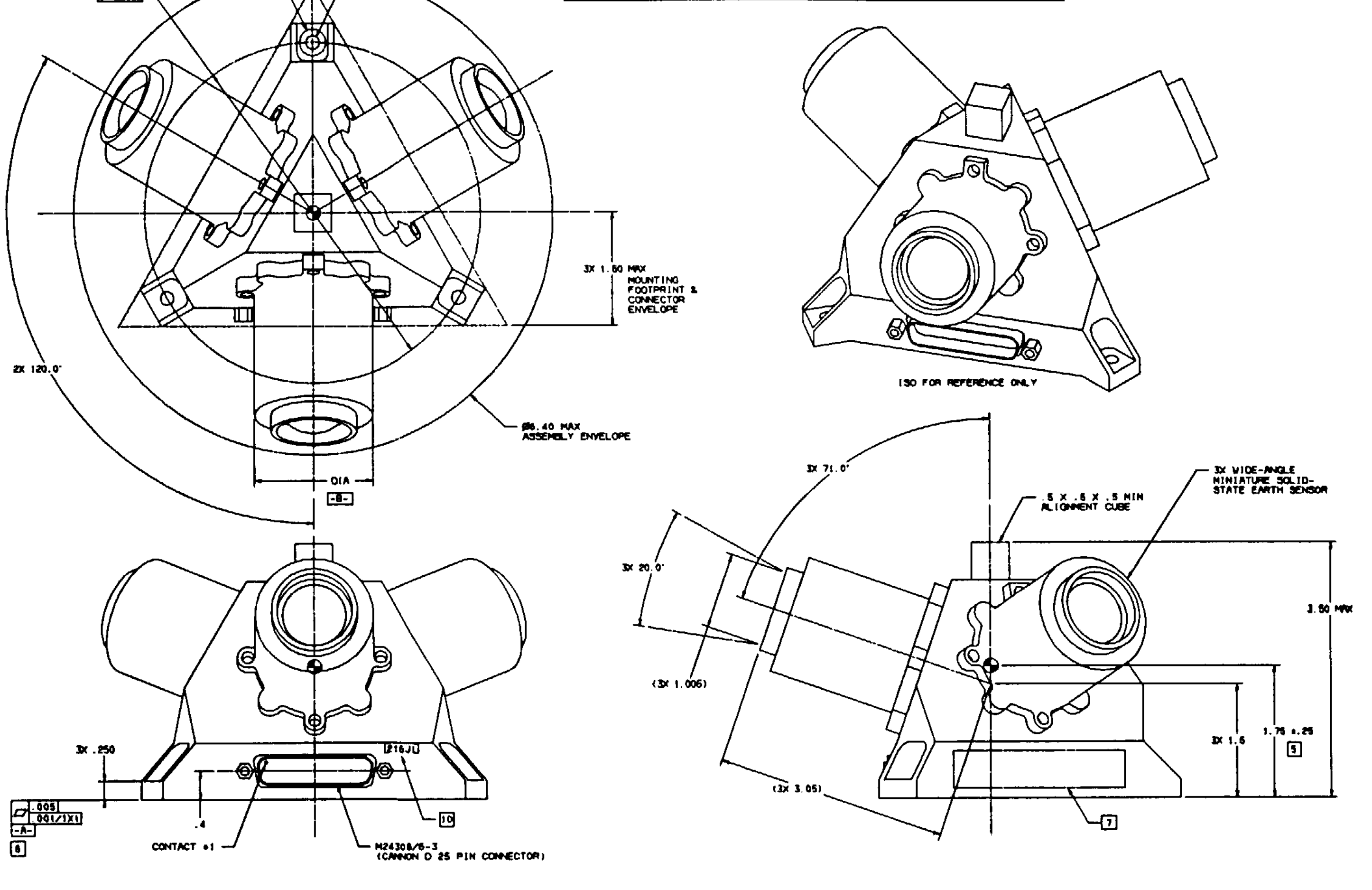
NOTES: UNLESS OTHERWISE SPECIFIED

1. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREIN IS APPROVED BY TRW REDONDO BEACH CALIFORNIA FOR USE IN THE APPLICATION(S) SPECIFIED HEREIN. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVAL BY TRW OR NASA HEADQUARTERS.
2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 3.4 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 10.0 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E01-095.
7. PART IDENTIFICATION SHALL BE PER E01-095. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTOR SHALL BE EQUIPPED WITH CONNECTOR SAVER AND DUST COVER.
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUT WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATOR AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
11. PROVIDE A ⌀0.32 MINIMUM FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER / TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF UNIT.
12. MOUNTING PROVISIONS FOR THE ALIGNMENT CUBE SHALL NOT OBSTRUCT ANY EXPOSED SURFACE MORE THAN 36X.

SOURCE CONTROL DRAWING

TRW
GYRO REFERENCE ASSEMBLY
NASV-4945
E 11982 C305624
SCALE 1/1

TRW		APPROVED SOURCES OF SUPPLY				APPLICATION	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E07-0366	XXXXX	TBD	TBD	EDO CORPORATION BARNES ENGINEERING SHELTON, CT	SSTI	305596



NOTES: UNLESS OTHERWISE SPECIFIED

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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 1.25 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 0.09 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E07-0366
7. PART IDENTIFICATION SHALL BE PER E07-0366. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT), THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. MARK APPROPRIATE UNIT DESIGNATOR WITH .18 MIN HIGH CHARACTERS. LOCATE APPROXIMATELY AS SHOWN.
11. PROVIDE A Ø0.35 MINIMUM FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER / TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF UNIT

SOURCE CONTROL DRAWING

NASV-4945

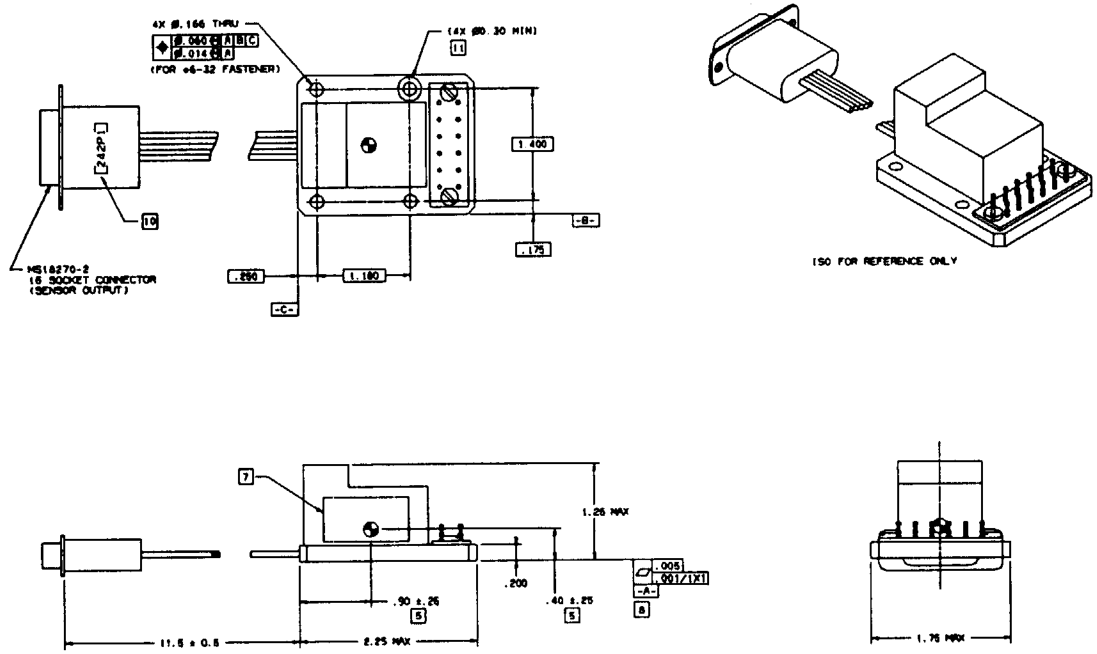
TRW

EARTH HORIZON SENSOR ASSEMBLY

E 11982 C305625

SSTI 305598 E07-0366

TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	1
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E02-0324	H57N	NI-88-31227	NI-88-31227	IDEAS INC. COLOMBIA, MD	SSTI	305597



NOTES: UNLESS OTHERWISE SPECIFIED

1. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREIN IS APPROVED BY TRW REDONDO BEACH CALIFORNIA FOR USE IN THE APPLICATION(S) SPECIFIED HEREIN. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVAL BY TRW OR NASA HEADQUARTERS.
2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 0.3 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 1.6 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E02-0324.
7. PART IDENTIFICATION SHALL BE PER E02-0324. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS
10. MARK APPROPRIATE UNIT DESIGNATOR WITH .18 MIN HIGH CHARACTERS. LOCATE APPROXIMATELY AS SHOWN
11. PROVIDE A ⌀0.30 MINIMUM FLAT AREA ABOUT EACH MOUNTING HOLE FOR #6 WASHER / TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF UNIT

SOURCE CONTROL DRAWING

NASW-4945

TRW

THREE AXIS MAGNETOMETER SENSOR

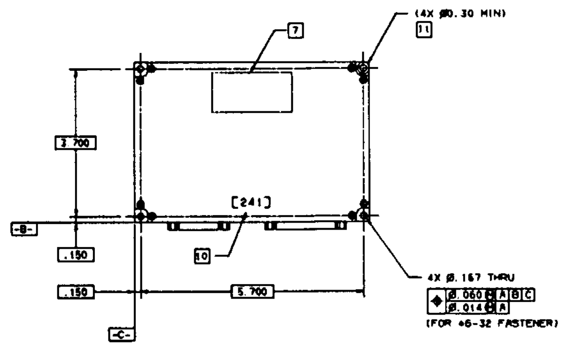
E 11982 C305626

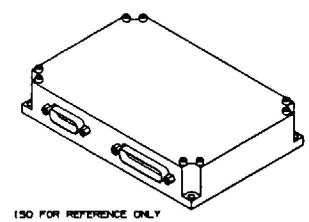
SSTI 305597 E02-0324

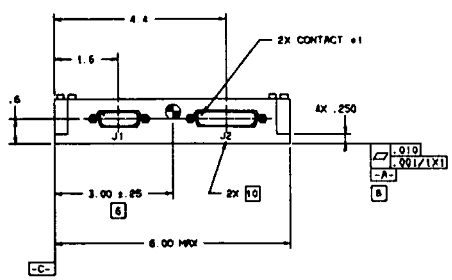
TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	1
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E02-0324	H57N	3490-000	3490-000	IDEAS INC. COLOMBIA, MD	SSTI	305597

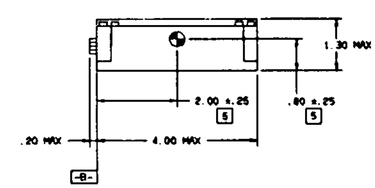
CONNECTOR DATA

REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	MIL-C-24308/8-2	SENSOR INPUT	15P
J2	MIL-C-24308/8-3	POWER, OUTPUT	25P









NOTES: UNLESS OTHERWISE SPECIFIED

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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 0.9 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 0.3 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E02-0324.
7. PART IDENTIFICATION SHALL BE PER E02-0324. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
11. PROVIDE A ⌀0.30 MINIMUM FLAT AREA ABOUT EACH MOUNTING HOLE FOR #6 WASHER / TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF UNIT.

SOURCE CONTROL DRAWING

SSTI	305597	X(-1)	X(-1)	E02-0324

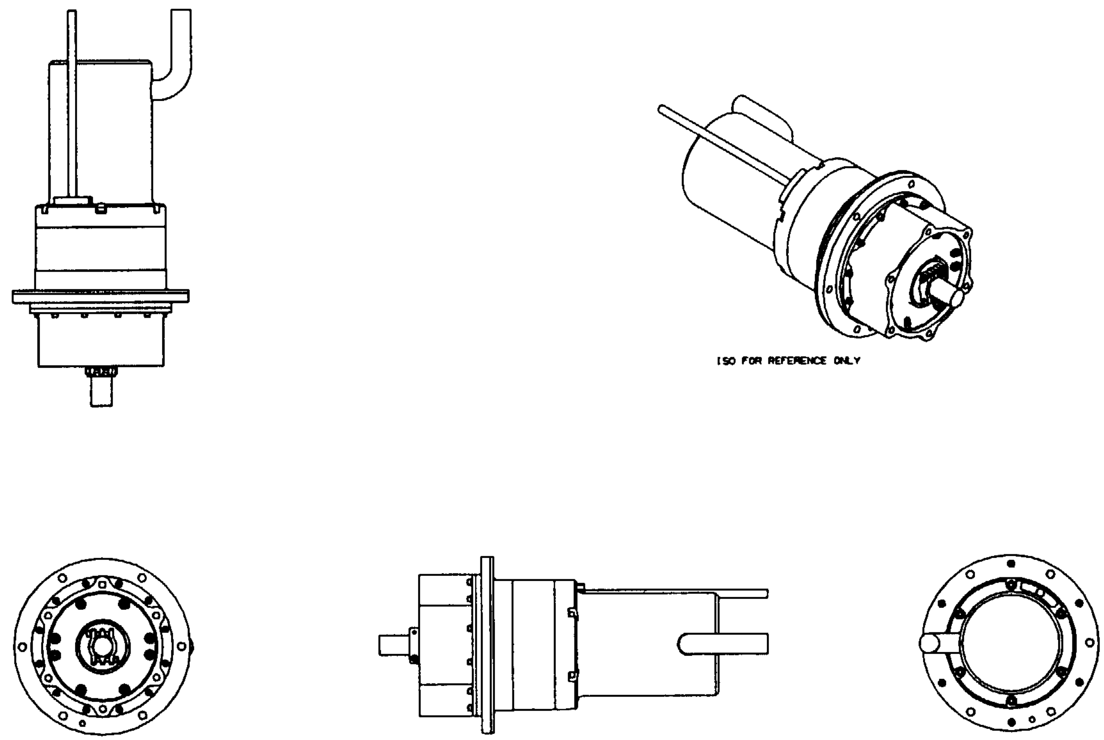
NASV-4945

TRW

THREE AXIS MAGNETOMETER ELECTRONICS

E 11982 C305627

TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	1
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E02-0322	25371	107685-1	107685	SCHAEFFER MAGNETICS INC. CHATSWORTH, CA	SST1	306597



NOTES: UNLESS OTHERWISE SPECIFIED

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2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 9.0 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 24.1 WATTS PEAK.
6. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT EOX-XXXX.
7. PART IDENTIFICATION SHALL BE PER E02-0322. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
11. PROVIDE A ⌀0.35 MINIMUM FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER / TOOL CLEARANCE.

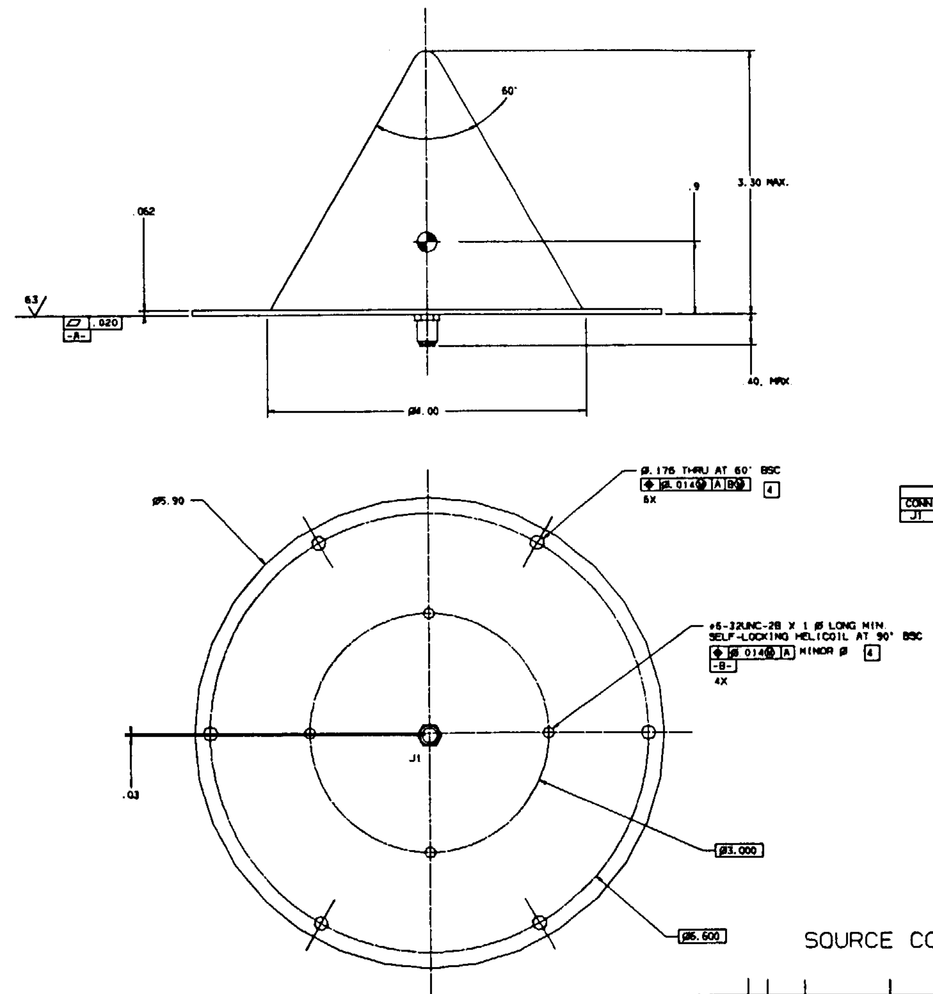
SOURCE CONTROL DRAWING

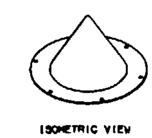
TRW

SOLAR ARRAY DRIVE ASSEMBLY

E 11982 C305628

TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION 1	
DASH NO.	APPL SPEC	FSCM NO.	PART NO.	DRAWING OR DOCUMENT #	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	N/A	14482	WJ-48915	637638	WATKINS-JOHNSON SAN JOSE, CA	SST1	305599





CONNECTOR TABLE			
CONN	TYPE	PART NUMBER	FUNCTION
J1	SMA	XXXXXX	RF INPUT, OUTPUT

NOTES: UNLESS OTHERWISE SPECIFIED

1. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR LISTED HEREON IS APPROVED BY TRW REDONDO BEACH CALIFORNIA FOR USE IN THE APPLICATION SPECIFIED HEREON. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVAL BY TRW.
2. IDENTIFICATION OF THE APPROVED SOURCE OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. ALL EXPOSED SURFACES EXCEPT THE MOUNTING SURFACES SHALL HAVE AN EMITTANCE OF GREATER THAN .80 AND BE PAINTED WHITE (S13G-LO). CHEM FILM HOLES AND MOUNTING SURFACES PER MIL-C-5541 CLASS 3.
4. UNIT IS TO BE MOUNTED AT EITHER THE INSERT PATTERN OR AT THE HOLE PATTERN. BOTH ARE NOT REQUIRED.
5. MAXIMUM WEIGHT OF THIS UNIT NOT TO EXCEED 0.5 LBS.
6. IDENTIFY PER MIL-STD-130.
7. ⊕ INDICATES CENTER OF GRAVITY FOR THE UNIT.

SOURCE CONTROL DRAWING

TRW

S-BAND ANTENNA

NASV-4945

EO4-4975

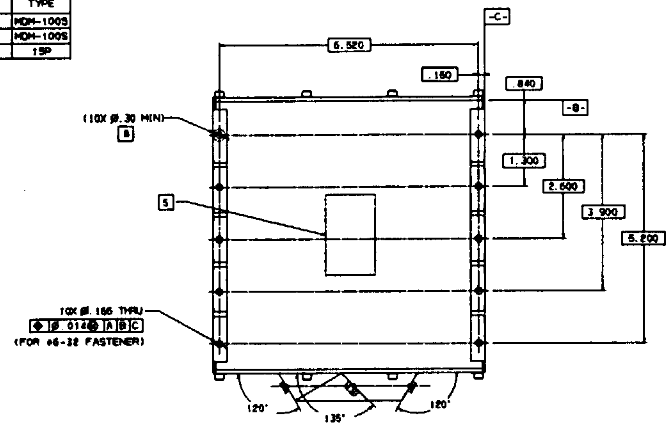
SST1 305599

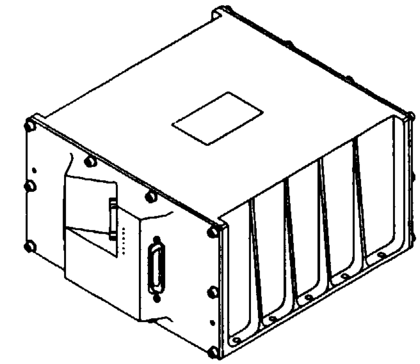
CATIA

E 11982 C305629

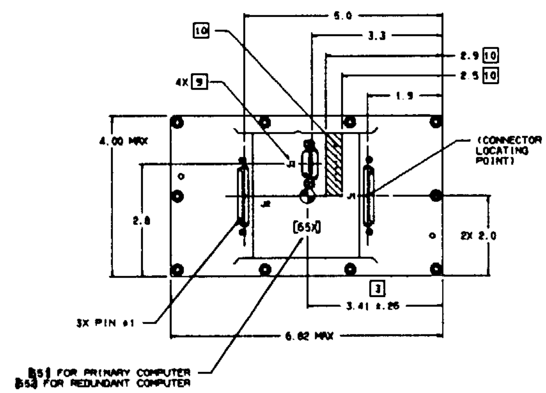
C305629

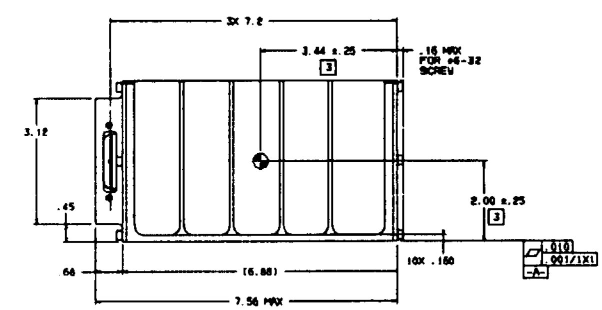
CONNECTOR DATA			
REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	2A047-214Y-001	I/O CONNECTOR	MDM-100S
J2	2A047-214Y-001	I/O CONNECTOR	MDM-100S
J3	2A068-013Y-001	POWER CONNECTOR	15P





ISO FOR REFERENCE ONLY





INTERFACE CONTROL DRAWING

NOTES: UNLESS OTHERWISE SPECIFIED

1. UNIT WEIGHT SHALL NOT EXCEED 7.0 LBS.
2. UNIT DISSIPATED POWER SHALL NOT EXCEED 47.6 WATTS PEAK.
3. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
4. UNIT SHALL COMPLY PER TRW DOCUMENT EQ20-106.
5. PART IDENT PER PR12-3-2. LOCATE APPROXIMATELY AS SHOWN.
6. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
7. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
8. PROVIDE A Ø.30 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #6 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
9. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS PER PR12-6-0103 WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
10. VENT HOLES SHALL REMAIN OPEN AND CLEAR OF PAINT, BONDING MATERIAL, WIRING, AND FOREIGN SUBSTANCES.

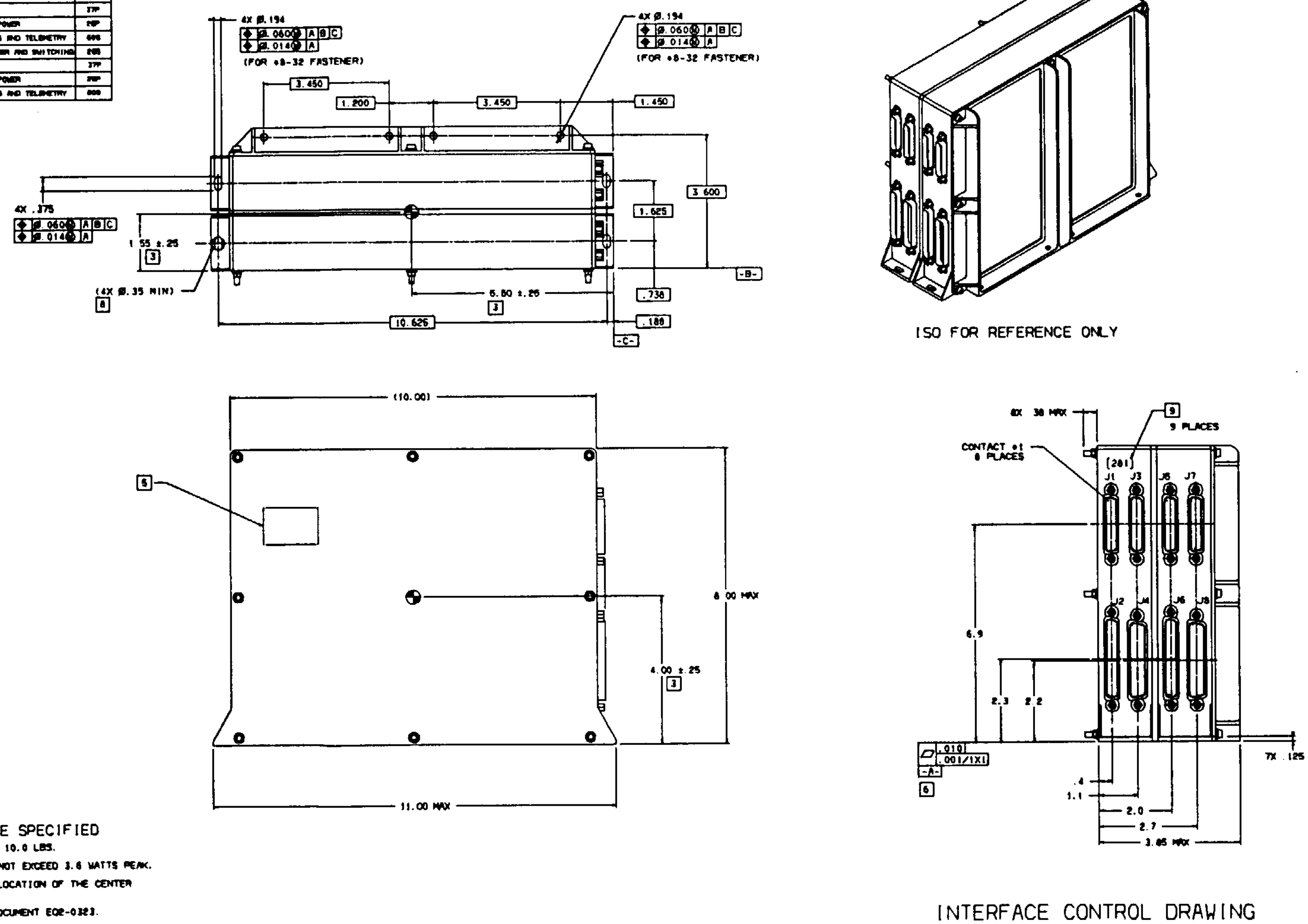
TRW

SPACECRAFT COMPUTER

E 11982 305630

PR12-6
EQ20-106 PR12-3
SST1

REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	2A014-058V	PRIMARY POWER AND SWITCHING	[illegible]
J2	2A014-054V	OUTPUT	37P
J3	2A014-053V	SECONDARY POWER	[illegible]
J4	2A014-060V	TEST POINTS AND TELEMETRY	[illegible]
J5	2A014-058V	PRIMARY POWER AND SWITCHING	[illegible]
J6	2A014-064V	OUTPUT	37P
J7	2A014-053V	SECONDARY POWER	[illegible]
J8	2A014-060V	TEST POINTS AND TELEMETRY	[illegible]



NOTES: UNLESS OTHERWISE SPECIFIED

1. UNIT WEIGHT SHALL NOT EXCEED 10.0 LBS.
2. UNIT DISSIPATED POWER SHALL NOT EXCEED 3.6 WATTS PEAK.
3. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
4. UNIT SHALL COMPLY PER TRW DOCUMENT EQ2-0323.
5. PART IDENTIFICATION PER EQ2-0323. LOCATE APPROXIMATELY AS SHOWN.
6. ALL SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN 0.80 (E.G., COATED PER PRS-33-12 (FLAT BLACK)). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEMICAL FILM.
7. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
8. PROVIDE A Ø.35 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
9. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATOR AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
10. CORRESPONDS TO UNIT ASSEMBLY 816125-1 (FOR REFERENCE).

INTERFACE CONTROL DRAWING

TRW

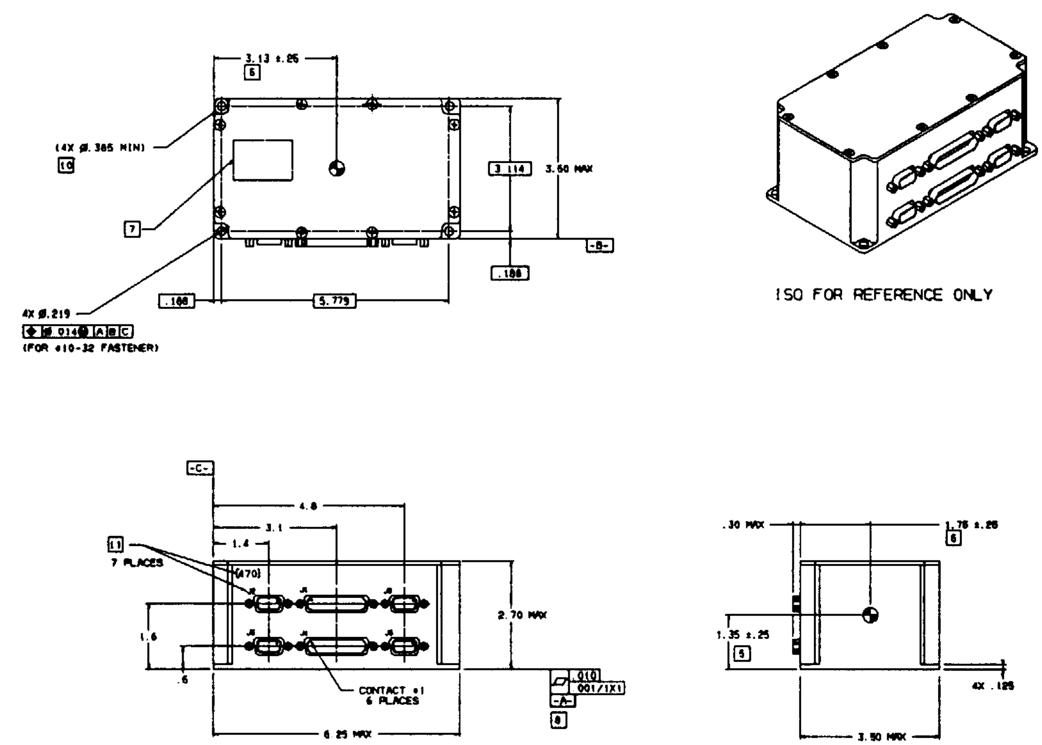
VALVE DRIVE ELECTRONICS

E 11982 305631

REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	MIL-C-24308/8-13	TBD	44P
J2	MIL-C-24308/6-2	TBD	15S
J3	MIL-C-24308/6-2	TBD	15S
J4	MIL-C-24308/8-13	TBD	44P
J5	MIL-C-24308/6-2	TBD	15S
J6	MIL-C-24308/6-2	TBD	15S

CONNECTOR DATA

TRW		1	APPROVED SOURCES OF SUPPLY			APPLICATION	1
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	E03-062	29371	TBD	TBD	[illegible]	SST1	308697



NOTES: UNLESS OTHERWISE SPECIFIED

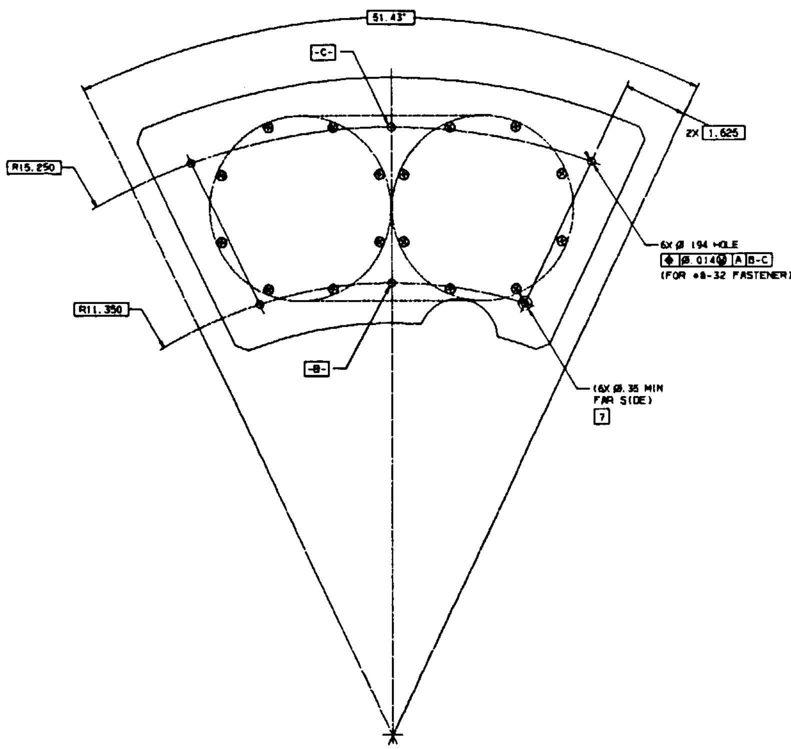
1. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREIN IS APPROVED BY TRW REDONDO BEACH CALIFORNIA FOR USE IN THE APPLICATION(S) SPECIFIED HEREIN. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVAL BY TRW OR NASA HEADQUARTERS.
2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 2.6 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED X.X WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT E03-062.
7. PART IDENTIFICATION PER E03-062. LOCATE APPROXIMATELY AS SHOWN.
8. ALL SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN 0.80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEMICAL FILM.
9. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. PROVIDE A Ø.385 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #10 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
11. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATOR AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

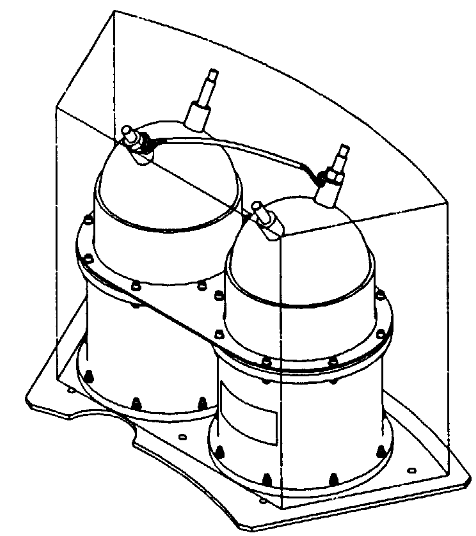
SOURCE CONTROL DRAWING

TRW

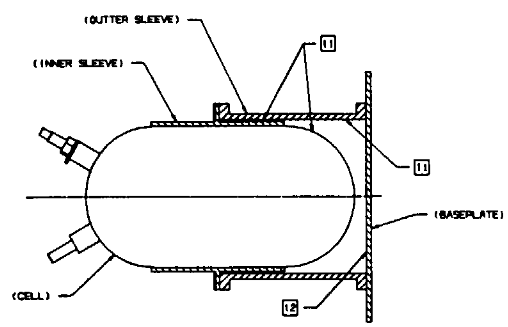
SOLAR ARRAY DRIVE ELECTRONICS

E 11982 C305632





ISO FOR REFERENCE ONLY



SECTION A-A
EMITTANCE REQUIREMENTS
2 PL

INTERFACE CONTROL DRAWING

NASW-4945

TRW

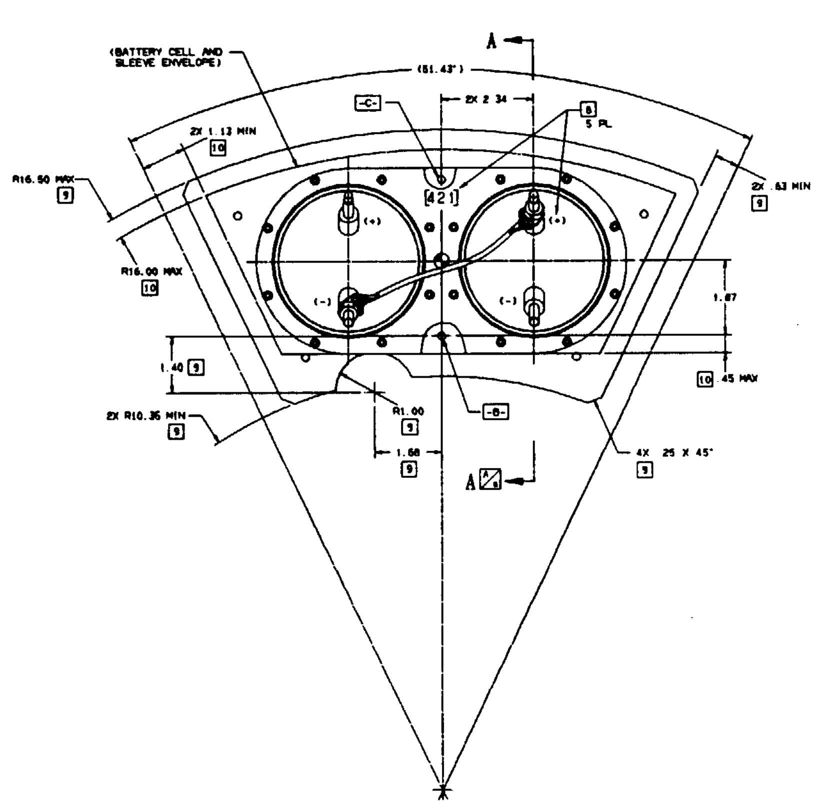
NIH, BATTERY MODULE

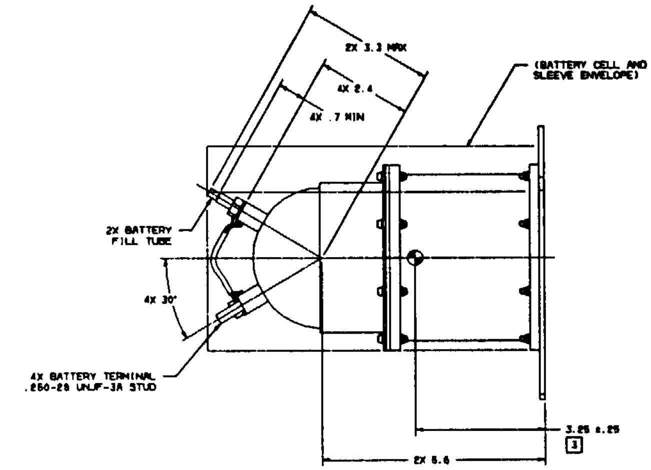
J 11982 305633

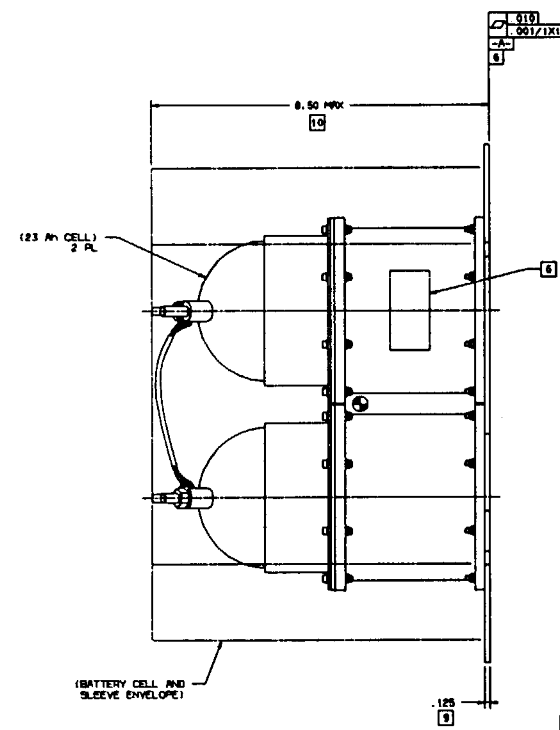
E01-058

CATIA

FRAME 1







NOTES: UNLESS OTHERWISE SPECIFIED

1. UNIT WEIGHT SHALL NOT EXCEED 10.0 LBS.
2. UNIT DISSIPATED POWER SHALL NOT EXCEED 12.9 WATTS PEAK.
3. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY
4. UNIT SHALL COMPLY PER TRW DOCUMENT E03-068.
5. PART IDENT PER E03-058. LOCATE APPROXIMATELY AS SHOWN.
6. THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
7. PROVIDE A Ø.36 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF UNIT.
8. MARK APPROIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATOR AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
9. BATTERY BASEPLATE ENVELOPE.
10. BATTERY CELL AND SLEEVE ENVELOPE.
11. NOTED SURFACES OF INNER SLEEVE, OUTER SLEEVE, AND CELL SHALL HAVE AN EMITTANCE LESS THAN .05
12. NOTED SURFACE OF BASEPLATE BELOW CELL SHALL HAVE AN EMITTANCE LESS THAN .05 (MULTI-LAYER INSULATION ACCEPTABLE).
13. HEATERS AND THERMOSTATS TBD

FRAME 2

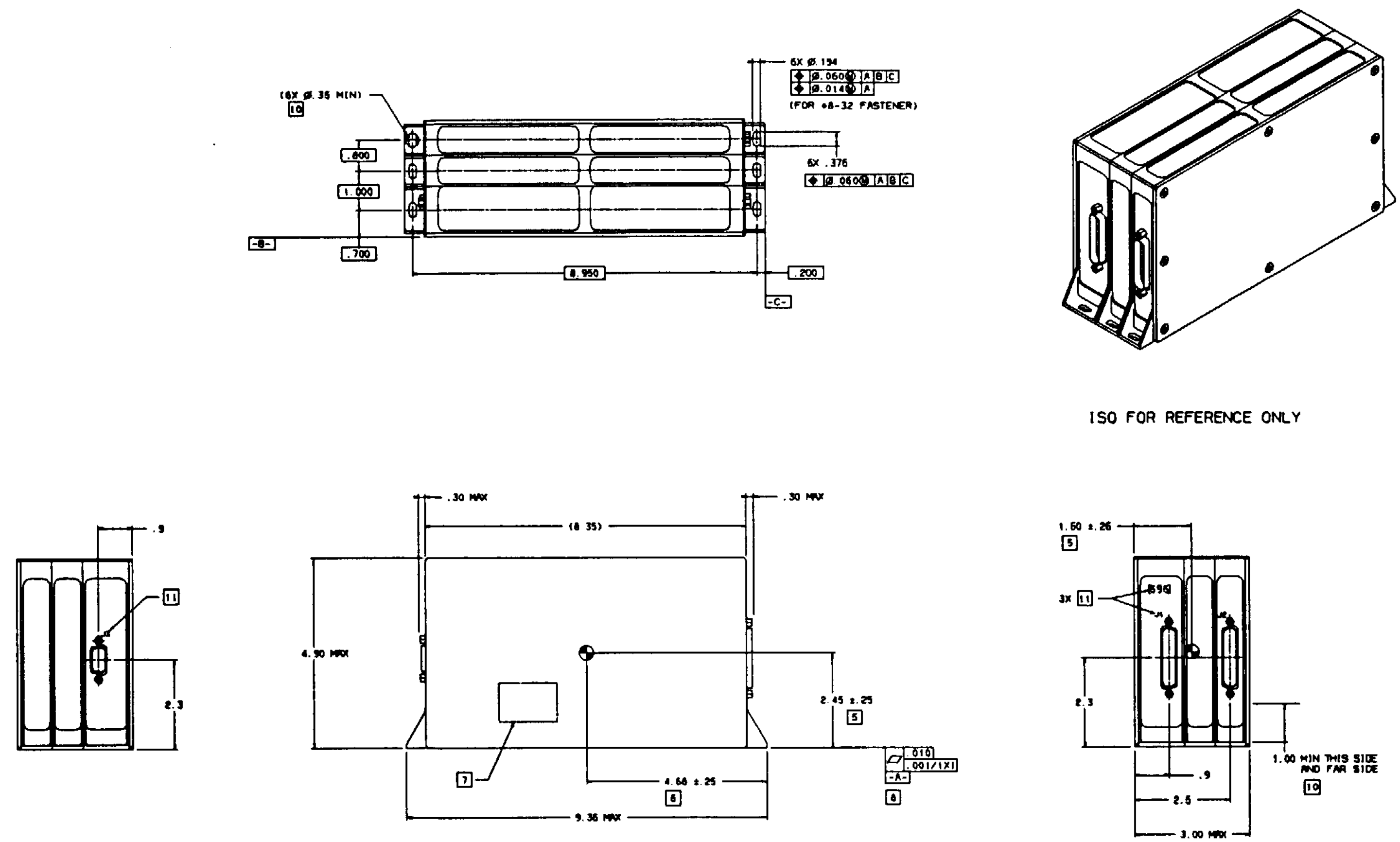
305633

R15.

TRW			APPROVED SOURCES OF SUPPLY			APPLICATION	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	XXXXXXXX	XXXXX	TBD	TBD	TBD	SSTI	306696

CONNECTOR DATA

REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	2A014-113V-001	XXXXFUNCTIONXXXX	25P
J2	2A014-113V-001	XXXXFUNCTIONXXXX	25P
J3	TBD	TEST CONNECTOR	9P



SOURCE CONTROL DRAWING

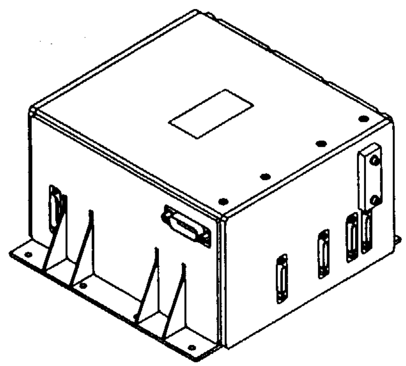
NOTES: UNLESS OTHERWISE SPECIFIED

1. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREIN IS APPROVED BY TRW REDONDO BEACH CALIFORNIA FOR USE IN THE APPLICATION(S) SPECIFIED HEREIN. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVIAL BY TRW OR NASA HEADQUARTERS.
2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 3.0 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 40.0 WATTS PEAK.
5. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT XXXXXXXX.
7. PART IDENTIFICATION PER XXXXXXXX. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. PROVIDE A Ø.36 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO NOTED DIMENSION.
11. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

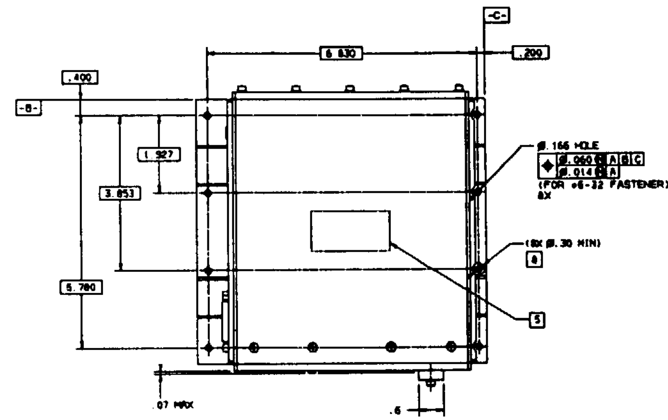
TRW
PHOTOVOLTAIC REGULATOR KIT EXPERIMENT
E 11982 C305635
NAS9-4946
SSTI 306696 TBD

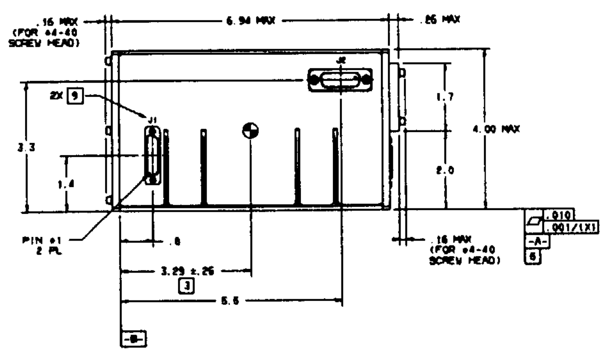
REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	MDM51SSPA174	1553 INTERFACE	MDM-51S
J2	2A014-042V-001	INPUT POWER	15P
J3	MDM31PCBRPA174	MSRW	MDM-31P
J4	MDM31PCBRPA174	HSI CRYOCOOLER DRIVER	MDM-31P
J5	MDM31PCBRPA174	LEISA CRYOCOOLER DRIVER	MDM-31P
J6	MDM31PCBRPA174	OPTICAL POINTING SYSTEM DRIVER	MDM-31P
J7	MDM51PCBRPA174	TEST	MDM-51P

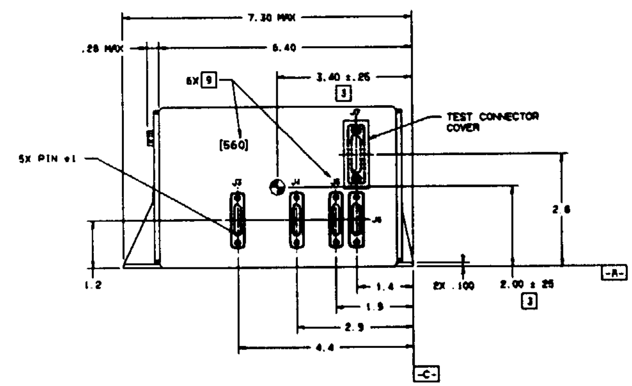
CONNECTOR DATA



ISO FOR REFERENCE ONLY







INTERFACE CONTROL DRAWING

NOTES: UNLESS OTHERWISE SPECIFIED

1. UNIT WEIGHT SHALL NOT EXCEED 8.0 LBS.
2. UNIT DISSIPATED POWER SHALL NOT EXCEED 28.0 WATTS PEAK.
3. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
4. UNIT SHALL COMPLY PER TRW DOCUMENT IF31-008.
5. PART IDENT SHALL BE PER PR12-3-2. LOCATE APPROXIAMTELY AS SHOWN.
6. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
7. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
8. PROVIDE A ⌀.30 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #6 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
9. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS PER PR12-6-0103 WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN

TRW

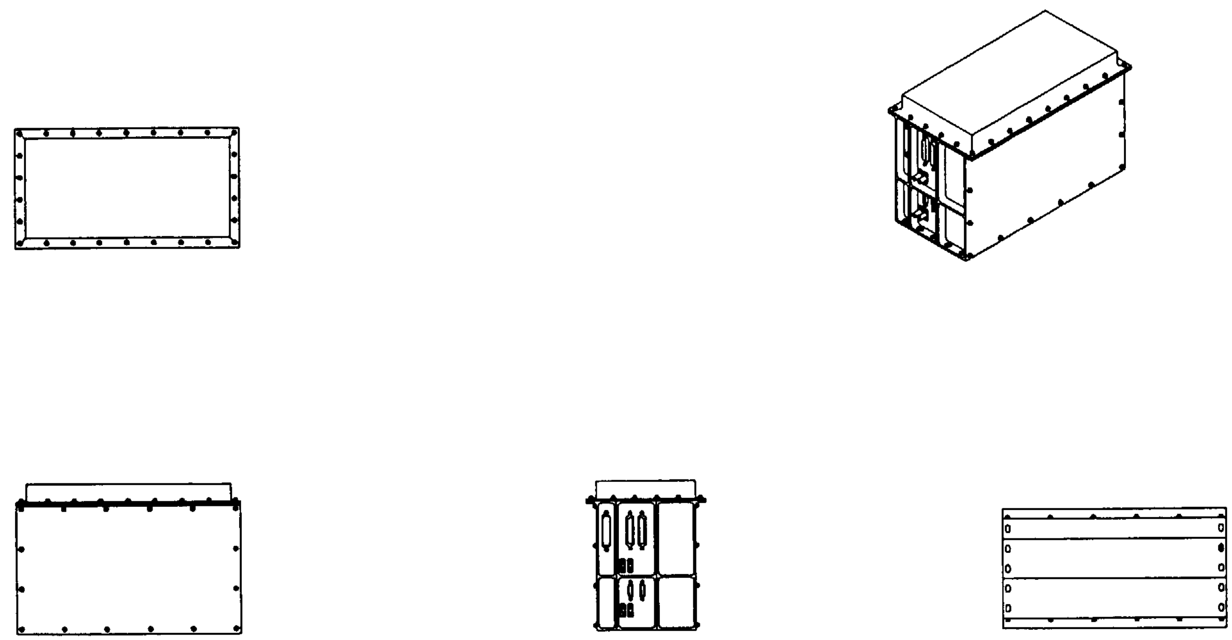
PAYLOAD ELECTRONICS ASSEMBLY

E 11982 305636

SSTI PR12-6 IF31-008 PR12-3

CONNECTOR DATA

REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	CANNON D	XXXXFUNCTIONXXXX	25P
J2	CANNON MDM	XXXXFUNCTIONXXXX	100P
J3	CANNON MDM	XXXXFUNCTIONXXXX	100P
J4	CANNON MDM	XXXXFUNCTIONXXXX	21P
J5	CANNON MDM	XXXXFUNCTIONXXXX	21P
J6	FIBER OPTIC	XXXXFUNCTIONXXXX	TBD
J7	FIBER OPTIC	XXXXFUNCTIONXXXX	TBD
J8	FIBER OPTIC	XXXXFUNCTIONXXXX	TBD
J9	FIBER OPTIC	XXXXFUNCTIONXXXX	TBD



INTERFACE CONTROL DRAWING

NOTES: UNLESS OTHERWISE SPECIFIED

1. UNIT WEIGHT SHALL NOT EXCEED 12.0 LBS.
2. UNIT DISSIPATED POWER SHALL NOT EXCEED 21.0 WATTS PEAK.
3. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
4. UNIT SHALL COMPLY PER TRW DOCUMENT EQ31-014.
5. PART IDENT PER EQ31-014. LOCATE APPROXIMATELY AS SHOWN.
6. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
7. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
8. PROVIDE A Ø.40 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #10 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
9. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATOR AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

SSTI

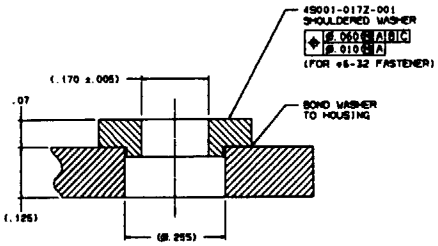
EQ31-014

TRW

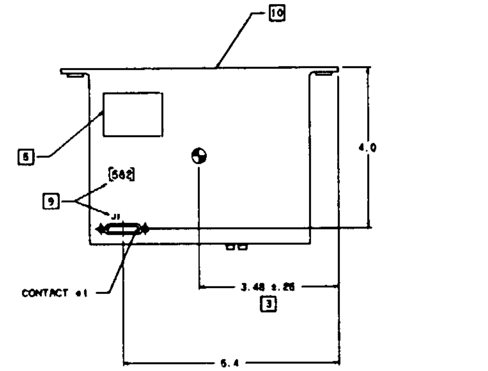
SOLID STATE RECORDER

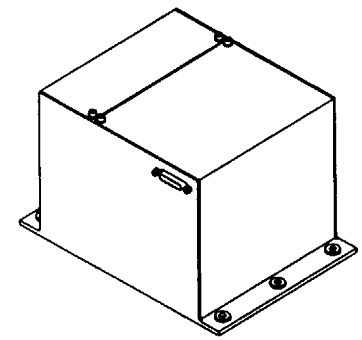
E 11982 305637

CONNECTOR DATA			
REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	MDM-31PXXL-A174	PAYLOAD ELECTRONICS I/F	31P

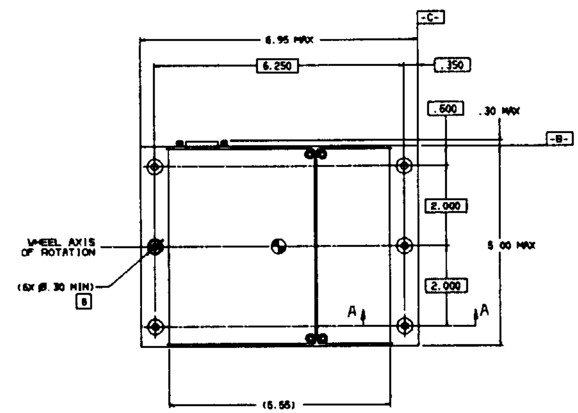


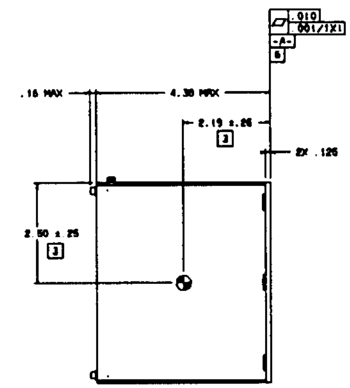
SECTION A-A
SCALE: 10/1
6 PLACES





ISO FOR REFERENCE ONLY



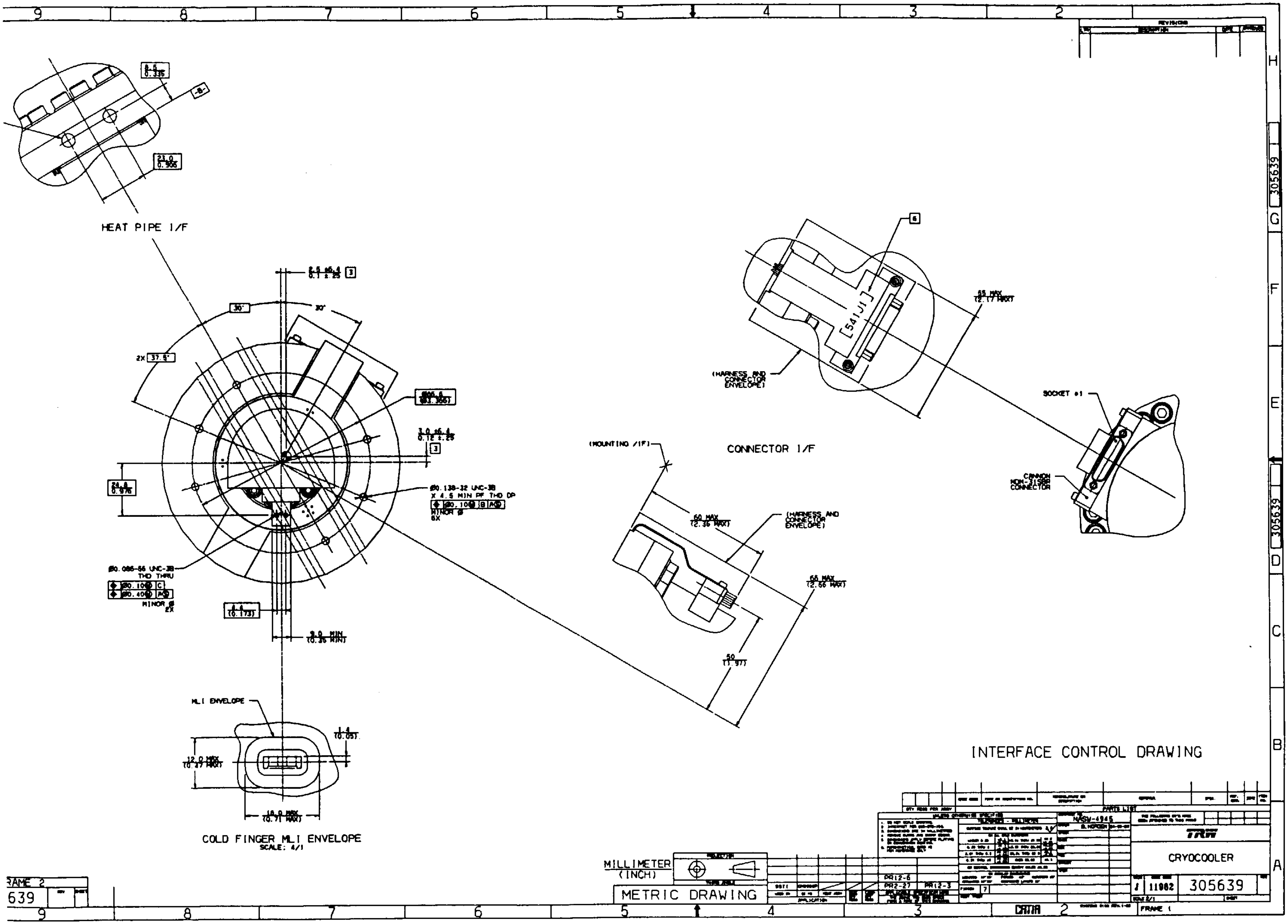


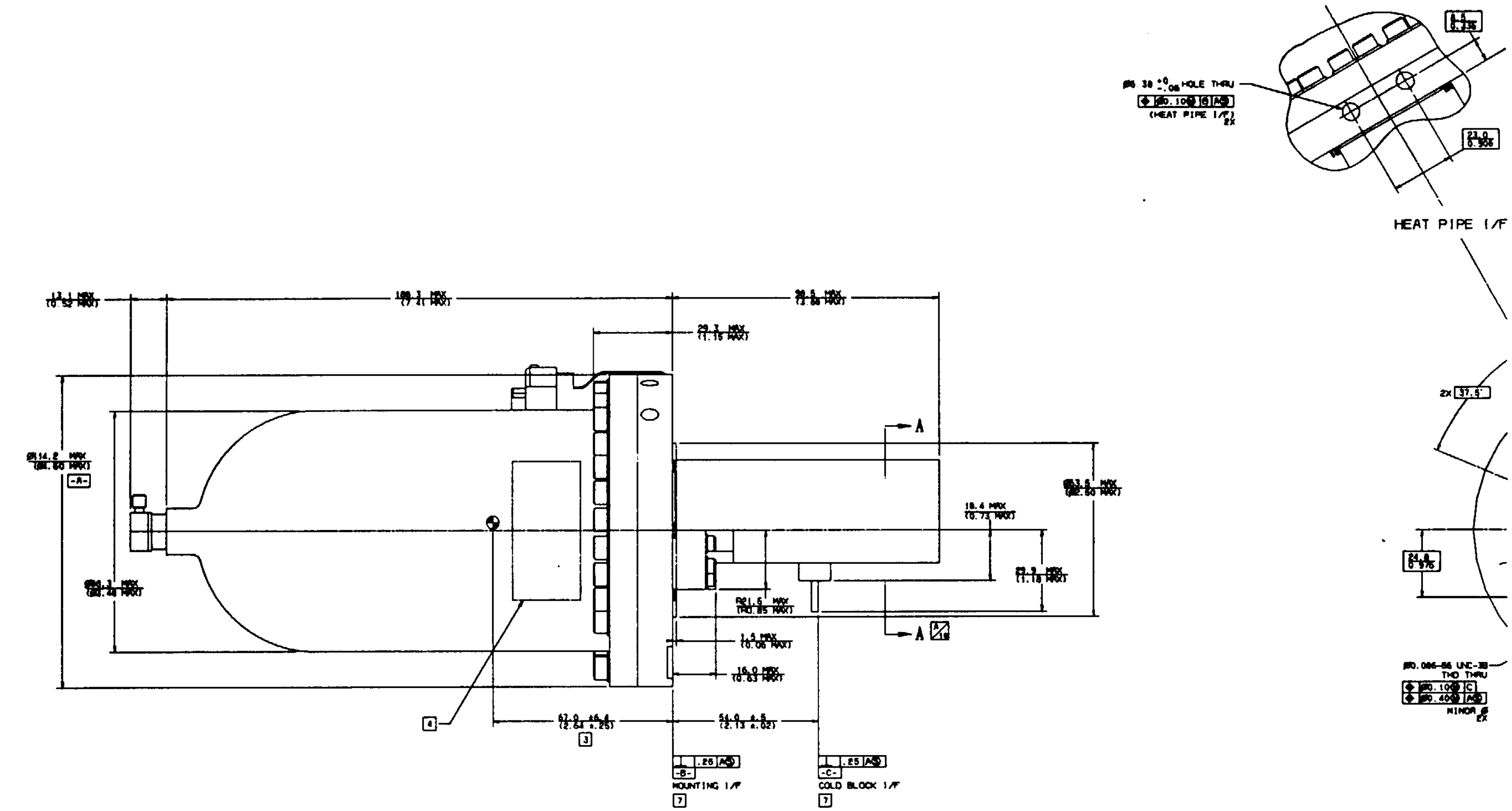
NOTES: UNLESS OTHERWISE SPECIFIED

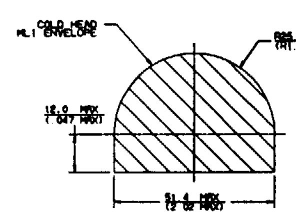
1. UNIT WEIGHT SHALL NOT EXCEED 5.50 LBS.
2. UNIT DISSIPATED POWER SHALL NOT EXCEED 6.00 WATTS PEAK.
3. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
4. UNIT SHALL COMPLY PER TRW DOCUMENT IF31-014.
5. PART IDENTIFICATION PER IF31-014. LOCATE APPROXIMATELY AS SHOWN.
6. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN 0.80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FLIM.
7. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS
8. PROVIDE A Ø.30 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #6 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
9. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATOR AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
10. BASE PLATE SHALL BE ELECTRICALLY INSULATED FROM SPACECRAFT.

INTERFACE CONTROL DRAWING

TRW
MAGNETICALLY SUSPENDED REACTION WHEEL ASSEMBLY
E 11982 305638
IF31-014


HEAT PIPE I/F
CONNECTOR I/F
(HARNESS AND CONNECTOR ENVELOPE)
SOCKET #1
CANNON MDM-31SBP CONNECTOR
(MOUNTING /IF)
65 MAX (2.17 MAX)
60 MAX (2.36 MAX)
66 MAX (2.66 MAX)
50 (1.97)
ML I ENVELOPE
COLD FINGER MLI ENVELOPE
SCALE: 4/1
12.0 MAX (0.47 MAX)
18.0 MAX (0.71 MAX)
INTERFACE CONTROL DRAWING
CRYOCOOLER
305639
MILLIMETER (INCH)
METRIC DRAWING



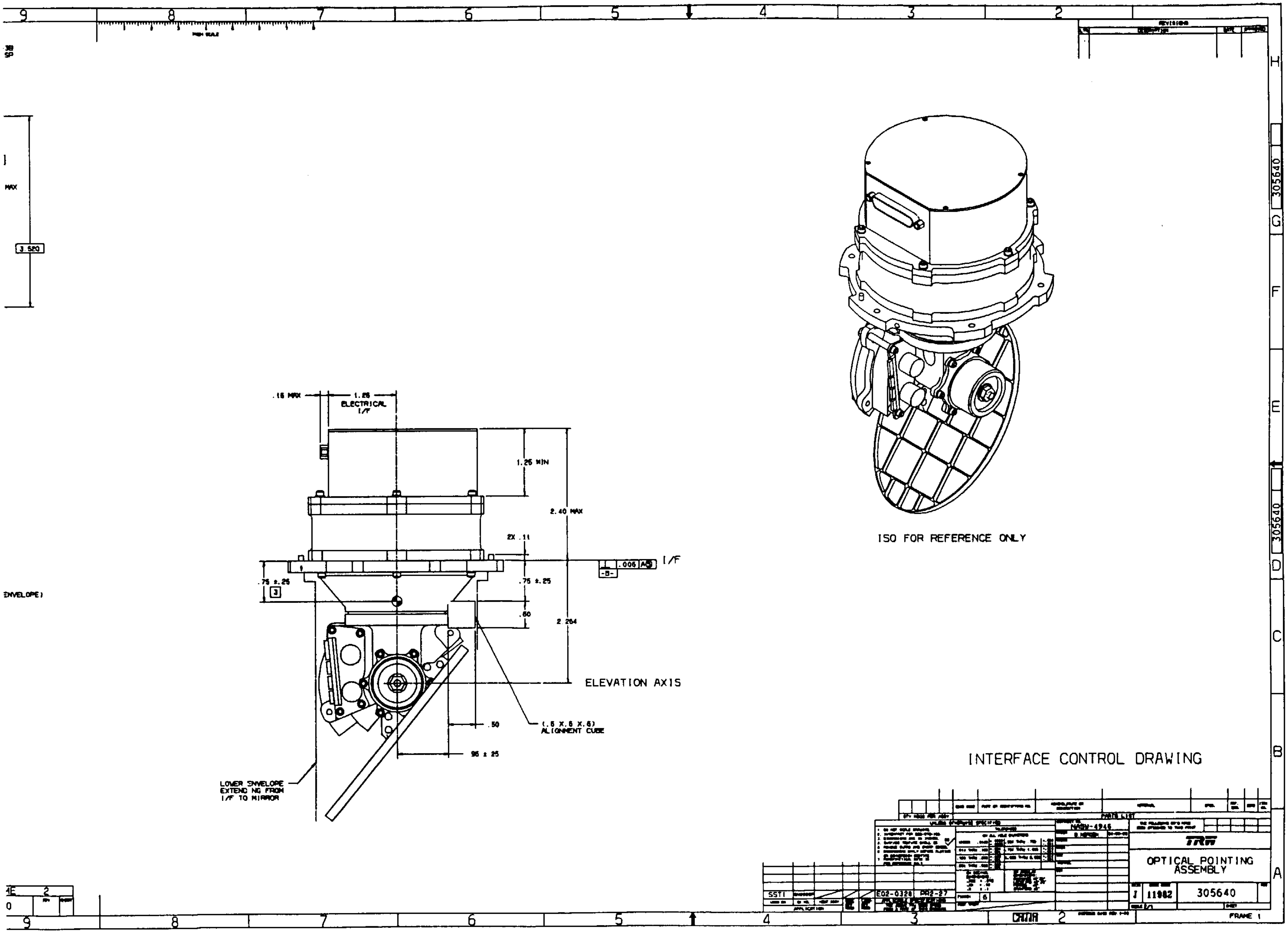


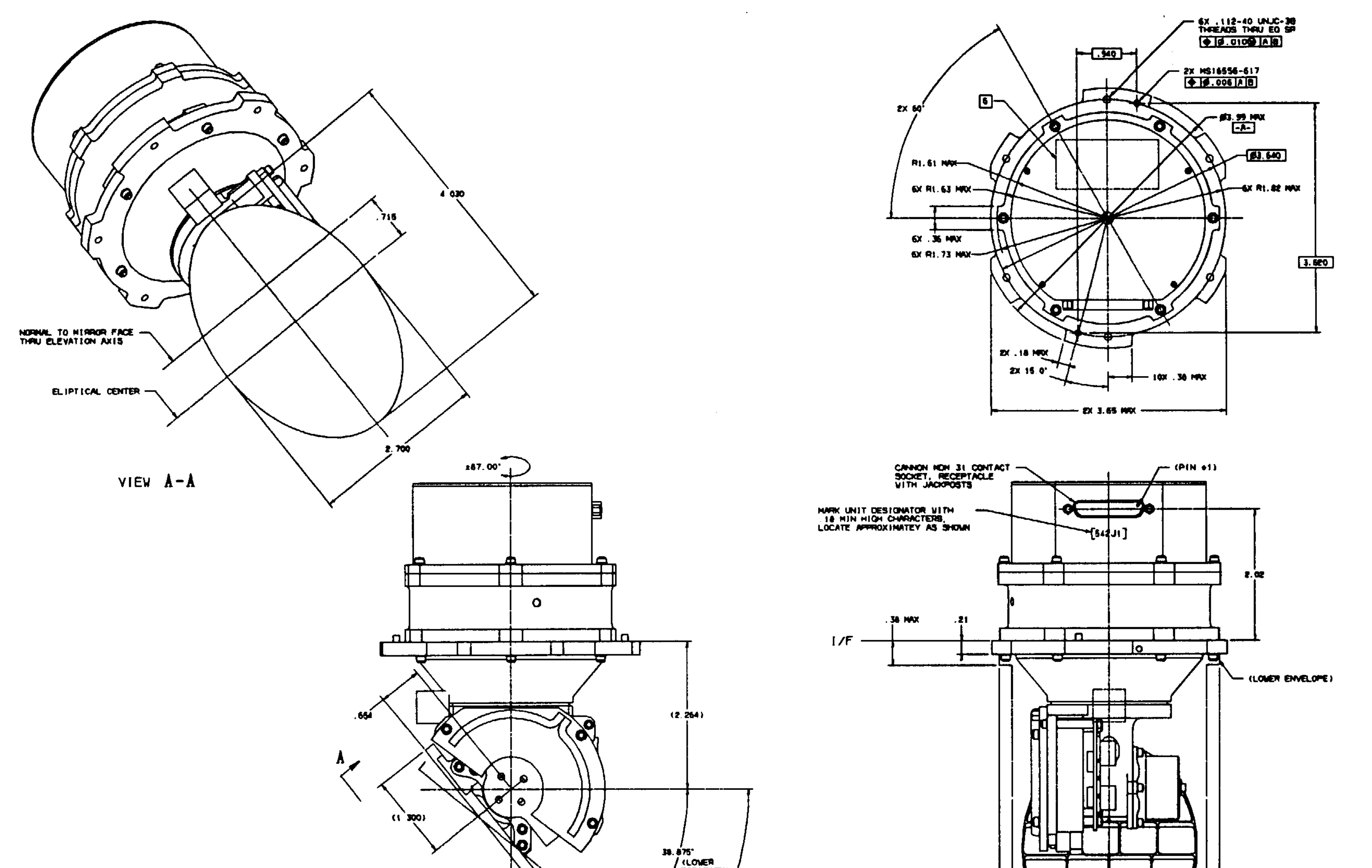
SECTION A-A
COLD HEAD MLI ENVELOPE

NOTES: UNLESS OTHERWISE SPECIFIED

1. UNIT WEIGHT SHALL NOT EXCEED 2.00 KG.
2. UNIT DISSIPATED POWER SHALL NOT EXCEED 17.05 WATTS PEAK.
3. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
4. PART IDENTIFICATION PER PR12-3-2. LOCATE APPROXIMATELY AS SHOWN.
5. CONNECTOR SHALL BE EQUIPPED WITH A CONNECTOR SAVER AND DUST COVER.
6. MARK APPROIATE REFERENCE DESIGNATOR CALLOUT PER PR12-6-0103 WITH .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.
7. CHEM FILM DONE PER PR2-27-3.

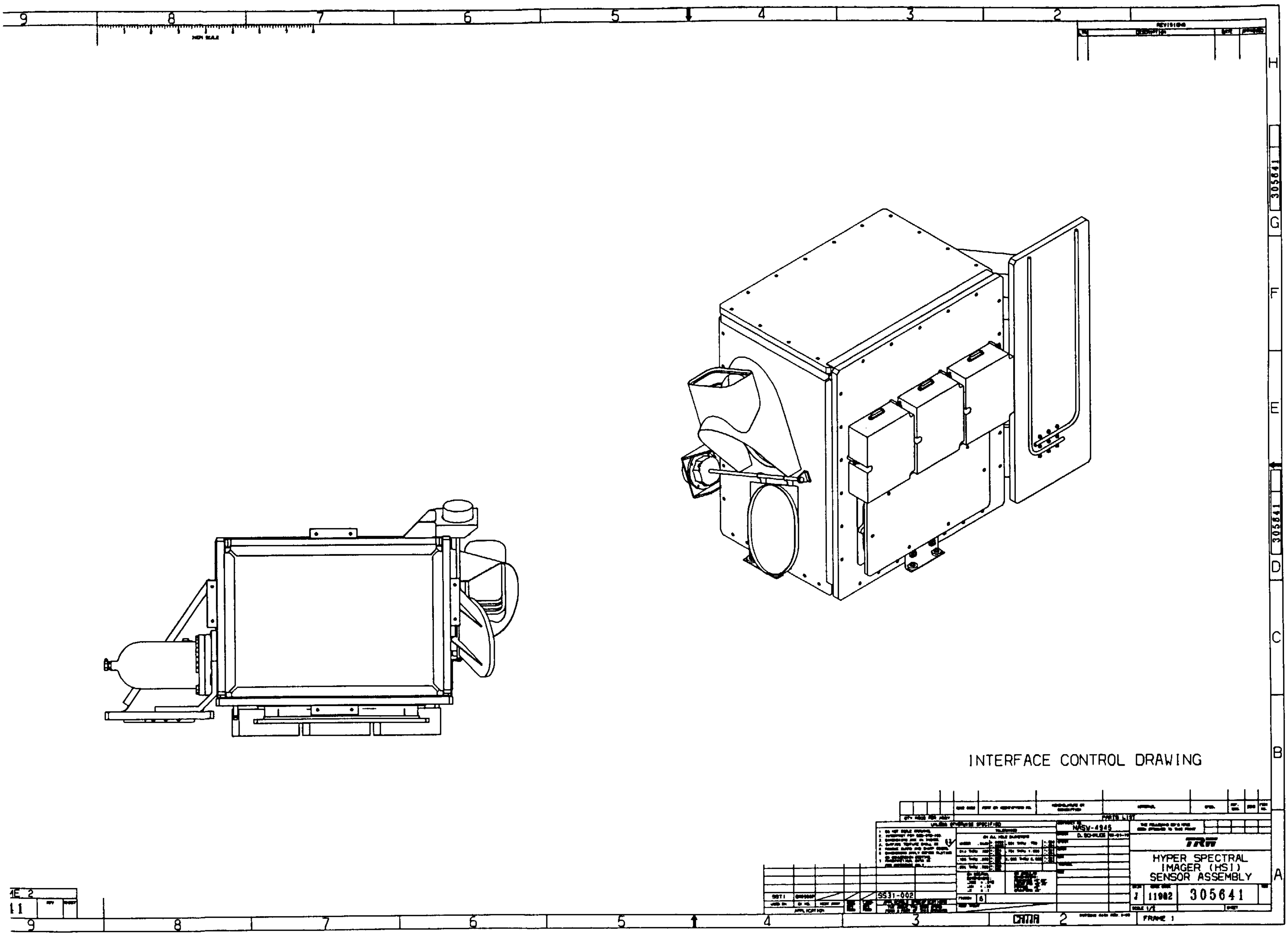
FRAME 2
305639


ISO FOR REFERENCE ONLY
ELEVATION AXIS
I/F
.006 A
-B-
.16 MAX
1.25 ELECTRICAL I/F
1.25 MIN
2.40 MAX
2X .11
.75 ± .25
.60
2.264
.50
.96 ± .25
(.6 X.6 X.6) ALIGNMENT CUBE
LOWER ENVELOPE EXTENDING FROM I/F TO MIRROR
3.520
INTERFACE CONTROL DRAWING
NAS9-4946
TRW
OPTICAL POINTING ASSEMBLY
11982
305640
E02-0328
SSTI
FRAME 1

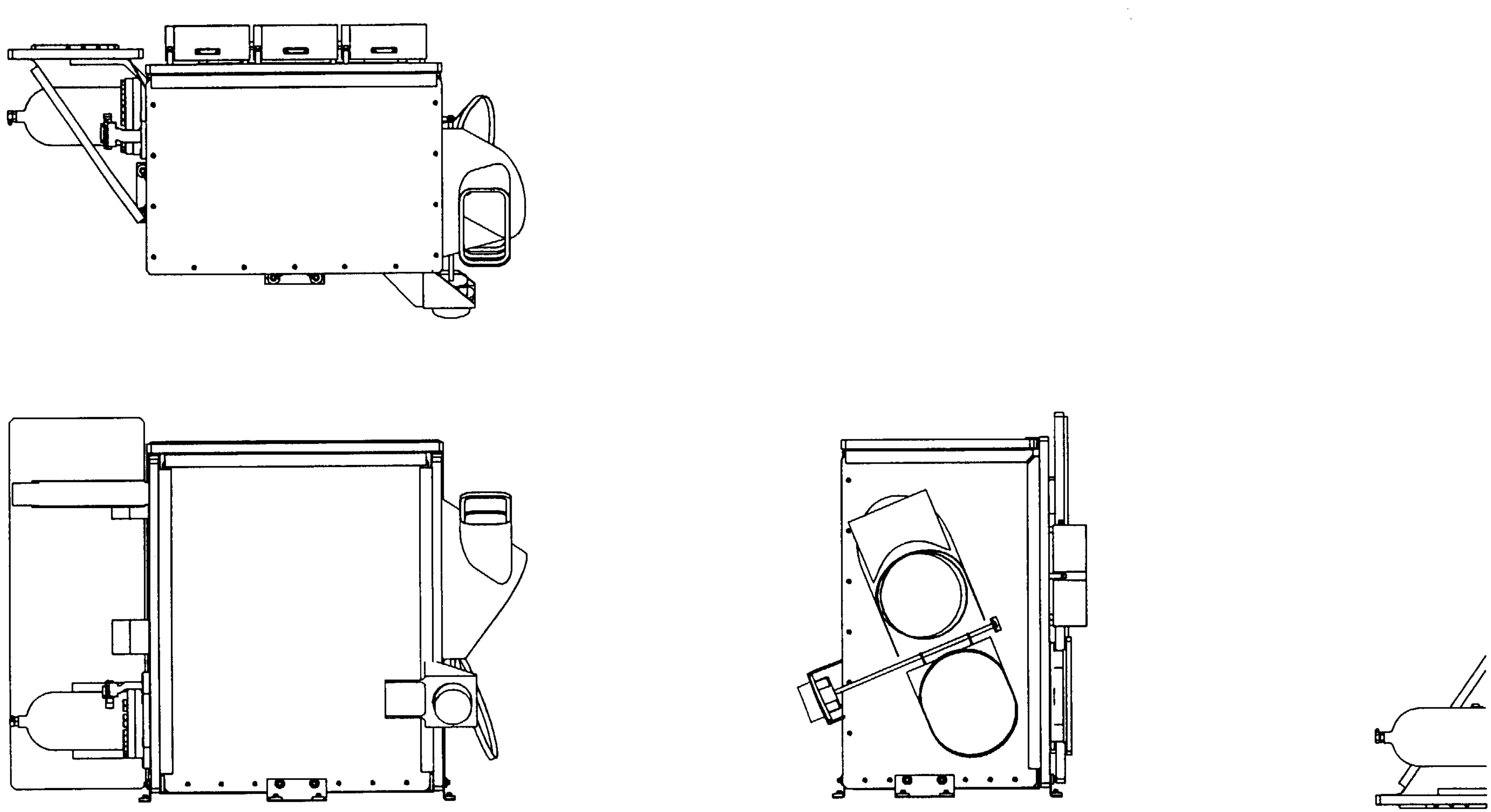


NOTES: UNLESS OTHERWISE SPECIFIED

1. UNIT WEIGHT SHALL NOT EXCEED 1.65 LBS.
2. UNIT DISSIPATED POWER SHALL NOT EXCEED 5.4 WATTS PEAK.
3. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
4. UNIT SHALL COMPLY PER TRW DOCUMENT EQ2-0328.
5. PART IDENTIFICATION PER EQ2-0328. LOCATE APPROXIMATELY AS SHOWN.
6. ALL SURFACES EXCEPT THE MIRROR SURFACE SHALL BE COATED PER TRW SPACE AND TECHNOLOGY GROUP SPECIFICATION PR2-27-3 (CHEM FLIM).
7. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.



INTERFACE CONTROL DRAWING
TRW
HYPER SPECTRAL
IMAGER (HSI)
SENSOR ASSEMBLY
11982
305641
NASV-4945
SS31-002
FRAME 1



NOTES: UNLESS OTHERWISE SPECIFIED

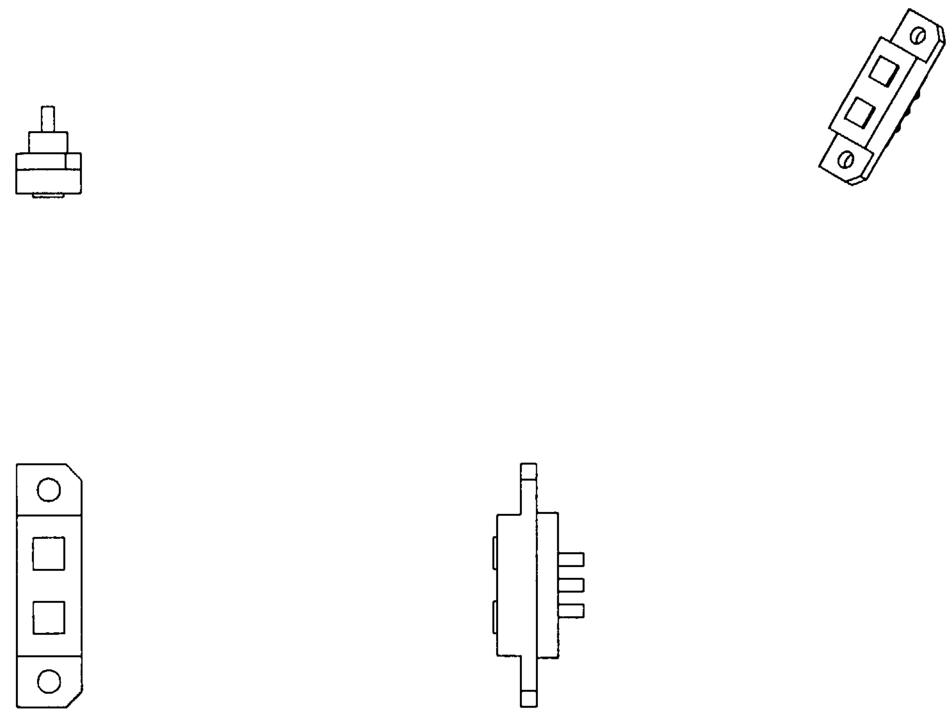
1. UNIT WEIGHT SHALL NOT EXCEED 50.7 LBS.
2. UNIT DISSIPATED POWER SHALL NOT EXCEED 50.5 WATTS PEAK.
3. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY
4. UNIT SHALL COMPLY PER TRW DOCUMENT SS31-002.
5. PART IDENT PER SS31-002. LOCATE APPROXIMATELY AS SHOWN.
6. THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
7. PROVIDE A Ø.36 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF UNIT.
8. MARK APPROIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATOR AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

FRAME 2

305641

CONNECTOR DATA

REF DES	CONNECTOR PART #	FUNCTION
J1	CANNON MDM-XXP	XXXFUNCTIONXXX
J2	CANNON MDM-XXP	XXXFUNCTIONXXX
J3	CANNON MDM-XXP	XXXFUNCTIONXXX
J4	CANNON MDM-XXP	XXXFUNCTIONXXX

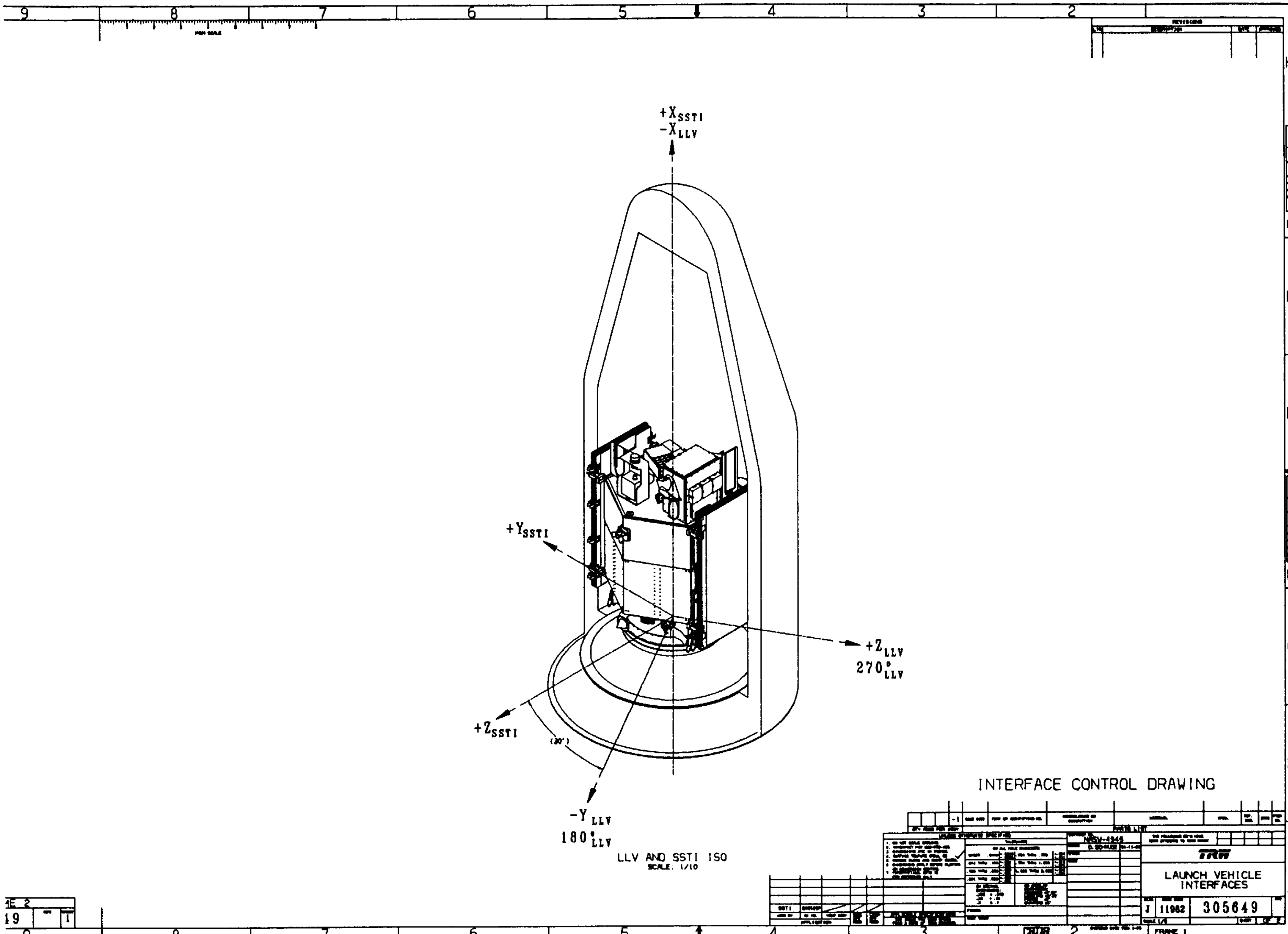


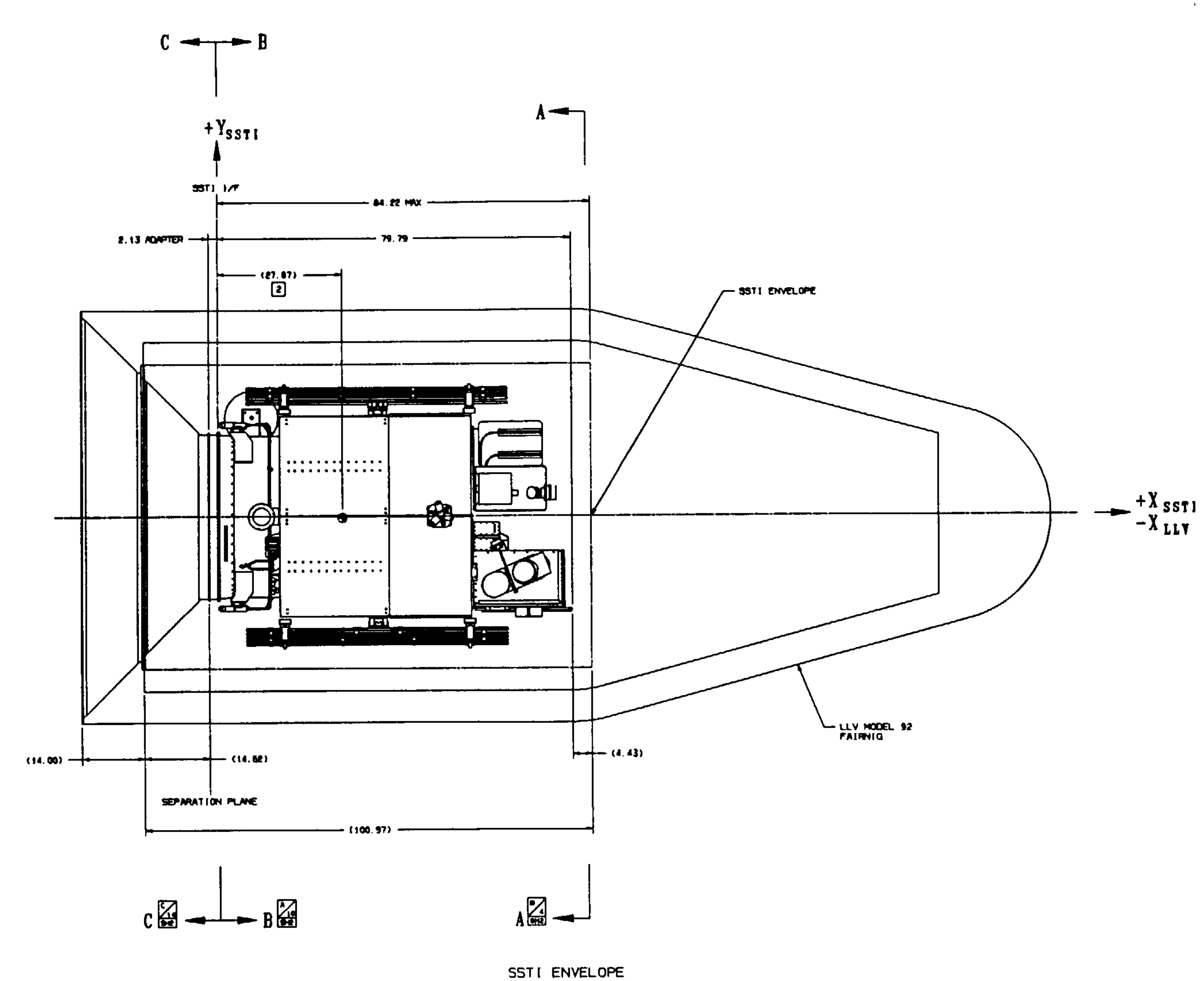
NOTES: UNLESS OTHERWISE SPECIFIED

1. UNIT WEIGHT SHALL NOT EXCEED X.X LBS.
2. UNIT DISSIPATED POWER SHALL NOT EXCEED X.X WATTS PEAK.
3. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
4. UNIT SHALL COMPLY PER TRW DOCUMENT EQX-XXXX.
5. PART IDENT PER EQX-XXXX. LOCATE APPROXIMATELY AS SHOWN.
6. ALL SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL BE COATED PER TRW SPACE AND TECHNOLOGY GROUP SPECIFICATION PRS-33-12 (FLAT BLACK).
7. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
8. PROVIDE A Ø.30 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #6 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
9. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATOR AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

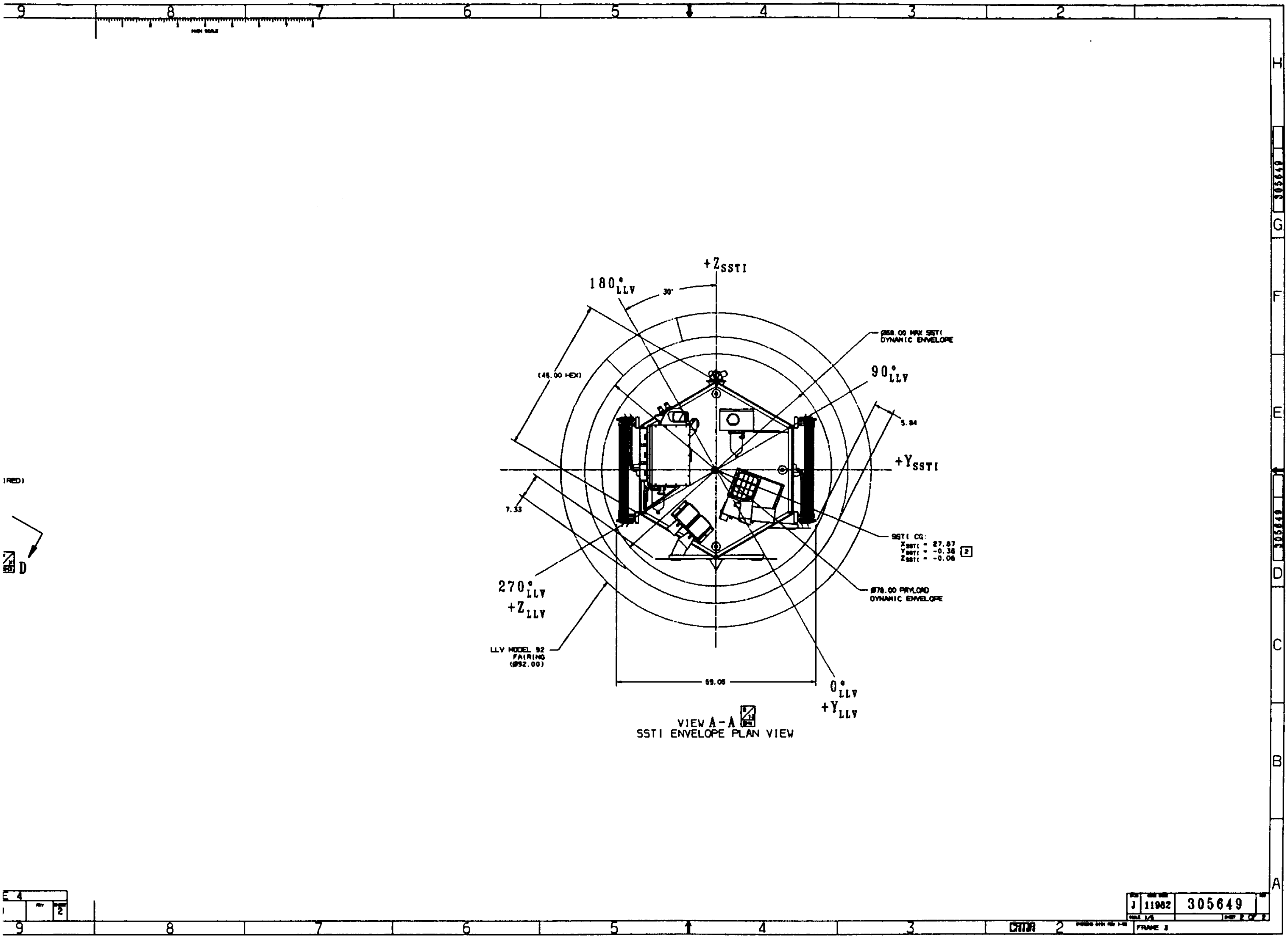
INTERFACE CONTROL DRAWING

	TRW
TITLE	COARSE SUN SENSOR
SIZE / CODE IDENT	E 11982
DWG NO.	305642
	EQX-XXXX PRS-33
	SSTI
	CATIA

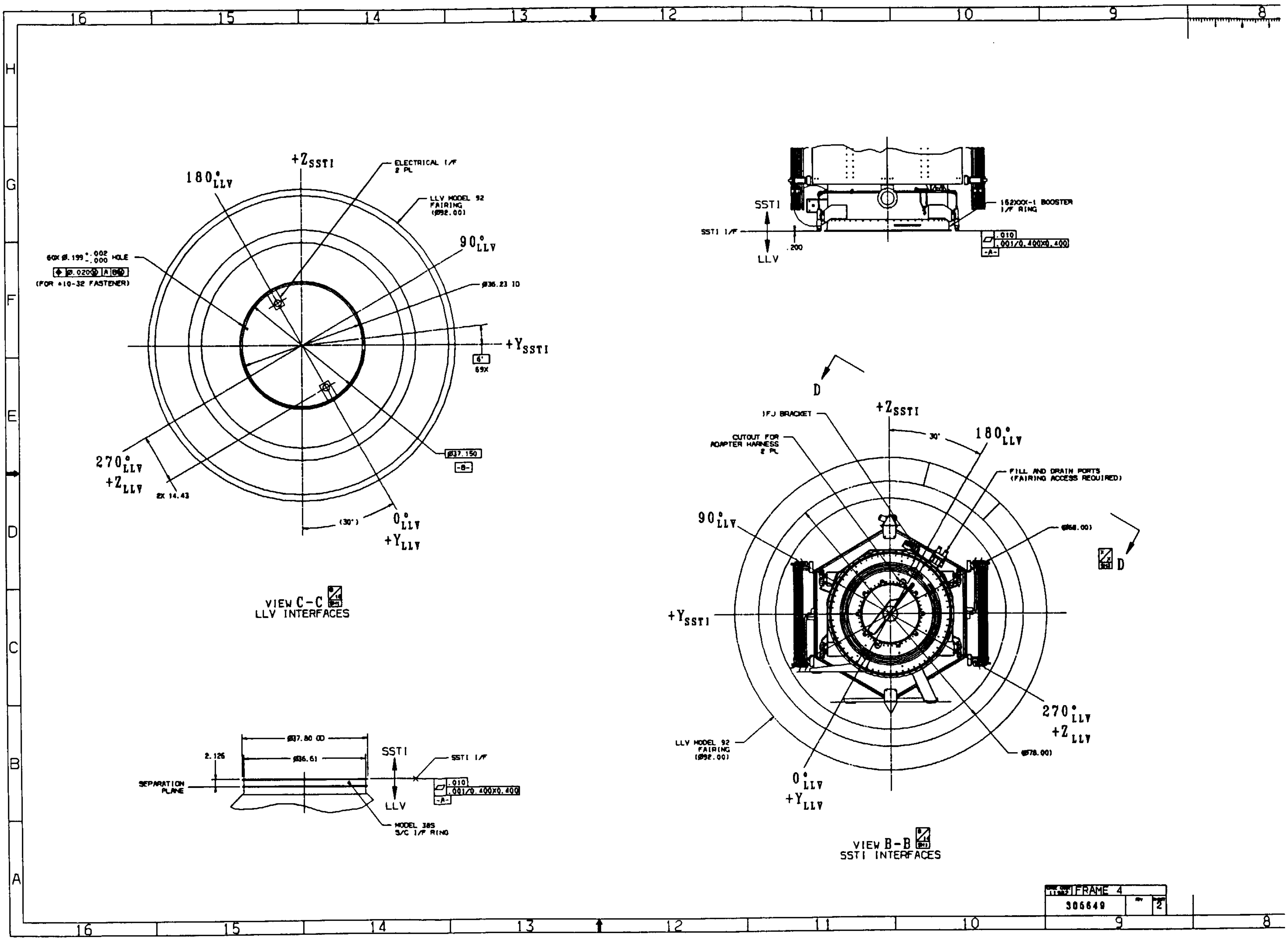

+X SSTI
-X LLV
+Y SSTI
+Z LLV
270° LLV
+Z SSTI
(30°)
-Y LLV
180° LLV
LLV AND SSTI ISO
SCALE: 1/10
INTERFACE CONTROL DRAWING
TRW
LAUNCH VEHICLE
INTERFACES
J 11982 305649
305649
FRAME 1



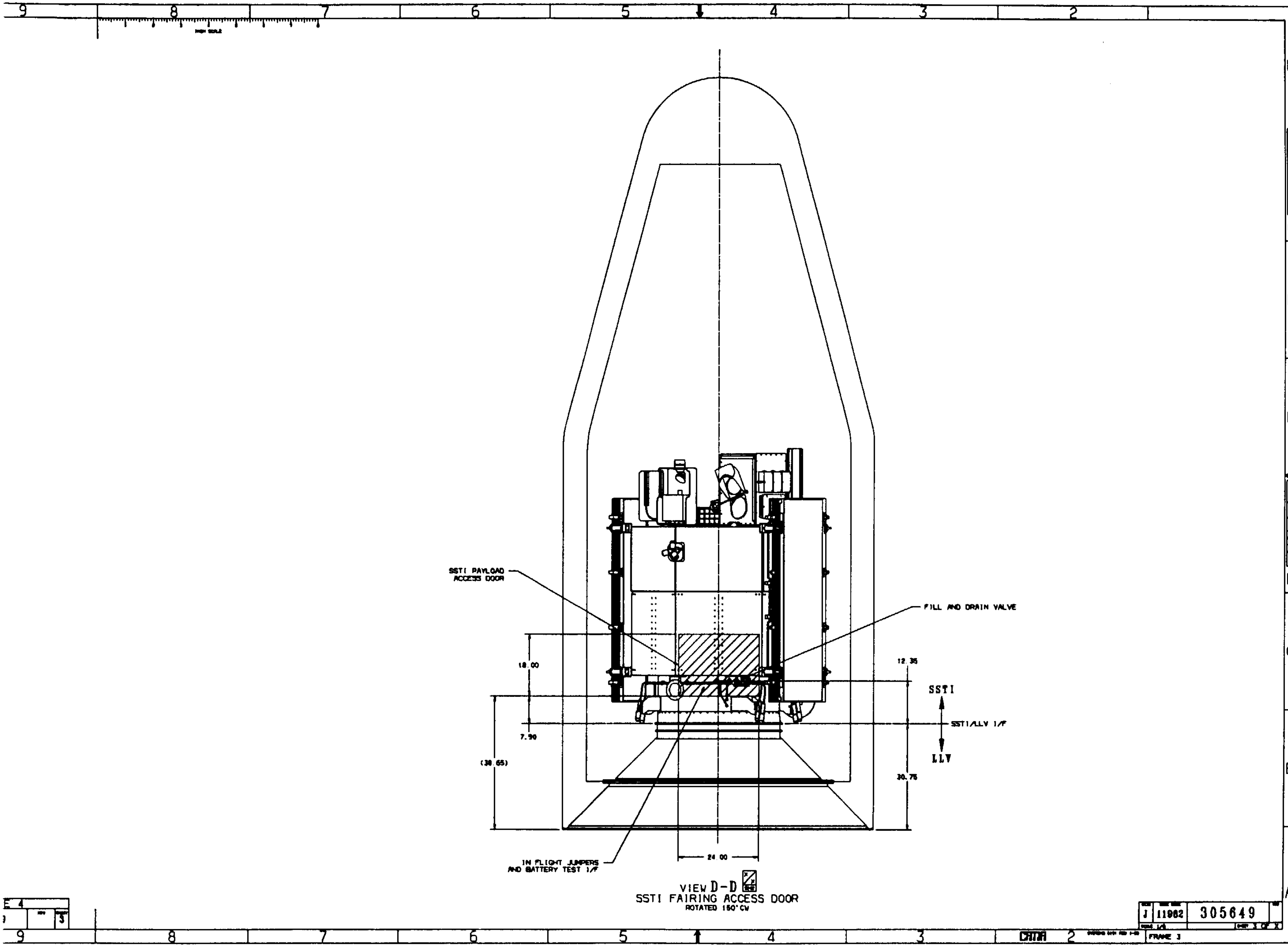
NOTES: UNLESS OTHERWISE SPECIFIED
1. SSTI MAX WEIGHT SHALL NOT EXCEED 860 LBS.
2 INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.



VIEW A-A
SSTI ENVELOPE PLAN VIEW



+Z SSTI
180° LLV
ELECTRICAL I/F 2 PL
LLV MODEL 92 FAIRING (Ø92.00)
90° LLV
60X Ø.199 +.002 -.000 HOLE
Ø.020 A B
(FOR #10-32 FASTENER)
Ø36.23 ID
+Y SSTI
6° 69X
Ø37.150
-B-
270° LLV
+Z LLV
2X 14.43
(30°)
0° LLV
+Y LLV
VIEW C-C
LLV INTERFACES
Ø37.80 OD
Ø36.61
2.126
SEPARATION PLANE
SSTI
LLV
SSTI I/F
.010
.001/0.400X0.400
-A-
MODEL 38S S/C I/F RING
SSTI
SSTI I/F
.200
LLV
152XXX-1 BOOSTER I/F RING
.010
.001/0.400X0.400
-A-
D
+Z SSTI
IFJ BRACKET
CUTOUT FOR ADAPTER HARNESS 2 PL
30°
180° LLV
FILL AND DRAIN PORTS (FAIRING ACCESS REQUIRED)
90° LLV
(Ø68.00)
D
+Y SSTI
270° LLV
+Z LLV
LLV MODEL 92 FAIRING (Ø92.00)
(Ø78.00)
0° LLV
+Y LLV
VIEW B-B
SSTI INTERFACES
FRAME 4
306649
2



VIEW D-D
SSTI FAIRING ACCESS DOOR
ROTATED 180° CW

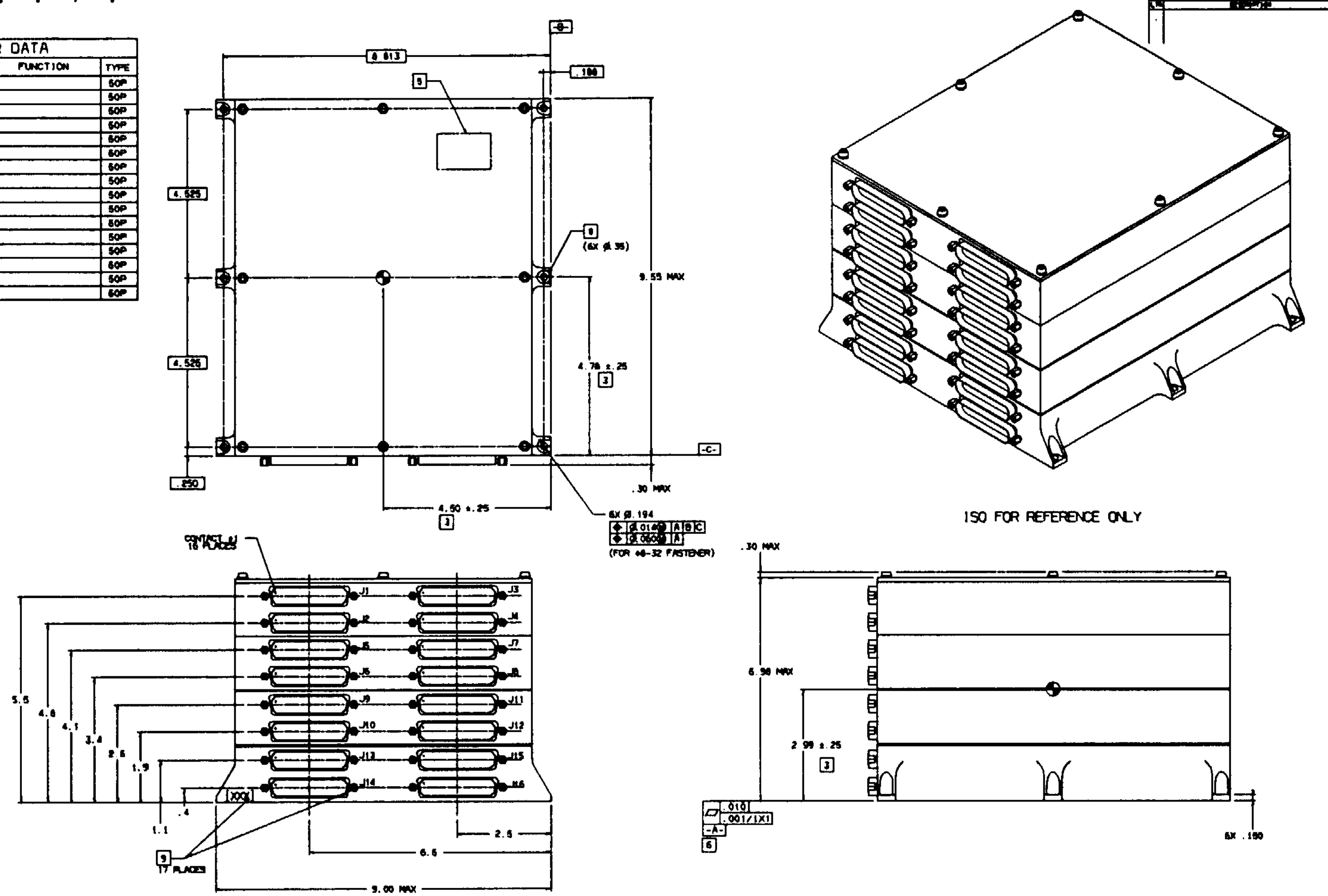
FRAME 4

305649

3

CONNECTOR DATA

REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	XXXXX-XXXY-001	TBD	50P
J2	XXXXX-XXXY-001	TBD	50P
J3	XXXXX-XXXY-001	TBD	50P
J4	XXXXX-XXXY-001	TBD	50P
J5	XXXXX-XXXY-001	TBD	50P
J6	XXXXX-XXXY-001	TBD	50P
J7	XXXXX-XXXY-001	TBD	50P
J8	XXXXX-XXXY-001	TBD	50P
J9	XXXXX-XXXY-001	TBD	50P
J10	XXXXX-XXXY-001	TBD	50P
J11	XXXXX-XXXY-001	TBD	50P
J12	XXXXX-XXXY-001	TBD	50P
J13	XXXXX-XXXY-001	TBD	50P
J14	XXXXX-XXXY-001	TBD	50P
J15	XXXXX-XXXY-001	TBD	50P
J16	XXXXX-XXXY-001	TBD	50P



NOTES: UNLESS OTHERWISE SPECIFIED

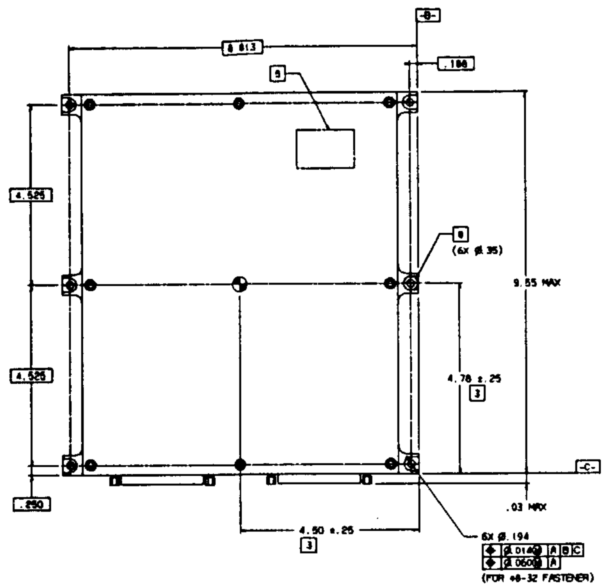
1. UNIT WEIGHT SHALL NOT EXCEED 9.5 LBS.
2. UNIT DISSIPATED POWER SHALL NOT EXCEED 63.2 WATTS PEAK AND 14.2 WATTS AVERAGE.
3. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
4. UNIT SHALL COMPLY PER TRW DOCUMENT EQX-XXX.
5. PART IDENTIFICATION PER PR12-3-2. LOCATE APPROXIMATELY AS SHOWN.
6. ALL SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN 0.80 (E.G., COATED PER PRS-33-12 (FLAT BLACK)). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEMICAL FILM.
7. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
8. PROVIDE A ⌀.38 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
9. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS PER PR12-6-0103 WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATOR AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

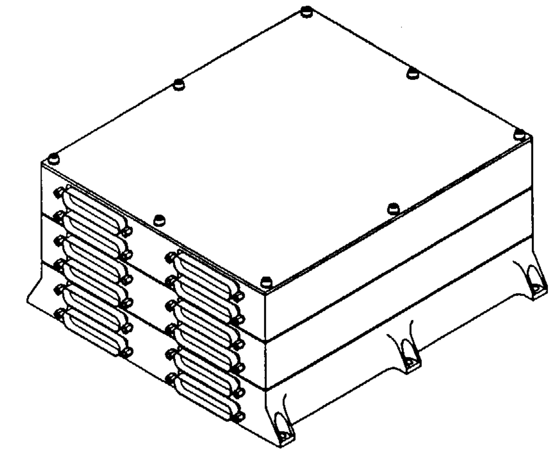
INTERFACE CONTROL DRAWING

HSI CONTROL ELECTRONICS			
E	11982	305650	

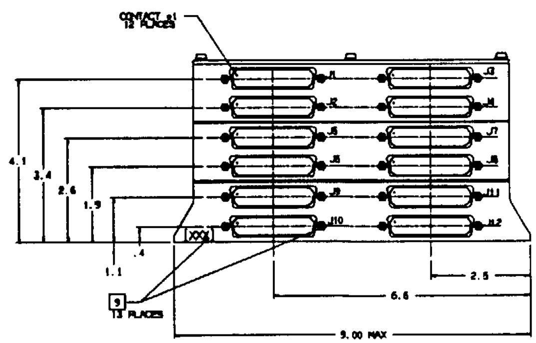
CONNECTOR DATA

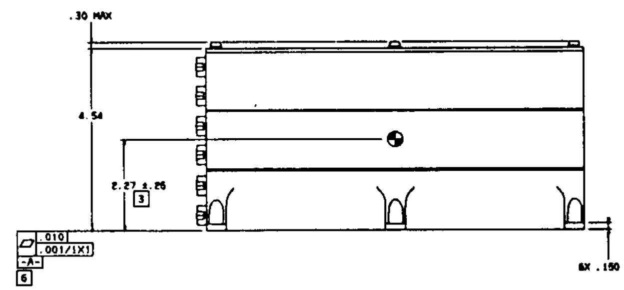
REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	XXXXX-XXXV-001	TBD	50P
J2	XXXXX-XXXV-001	TBD	50P
J3	XXXXX-XXXV-001	TBD	50P
J4	XXXXX-XXXV-001	TBD	50P
J5	XXXXX-XXXV-001	TBD	50P
J6	XXXXX-XXXV-001	TBD	60P
J7	XXXXX-XXXV-001	TBD	50P
J8	XXXXX-XXXV-001	TBD	50P
J9	XXXXX-XXXV-001	TBD	50P
J10	XXXXX-XXXV-001	TBD	50P
J11	XXXXX-XXXV-001	TBD	60P
J12	XXXXX-XXXV-001	TBD	60P





ISO FOR REFERENCE ONLY





NOTES: UNLESS OTHERWISE SPECIFIED

1. UNIT WEIGHT SHALL NOT EXCEED 7.7 LBS.
2. UNIT DISSIPATED POWER SHALL NOT EXCEED 32.8 WATTS PEAK AND 6.0 WATTS AVERAGE.
3. ⊕ INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
4. UNIT SHALL COMPLY PER TRW DOCUMENT EQX-XXX.
5. PART IDENTIFICATION PER PR12-3-2. LOCATE APPROXIMATELY AS SHOWN
6. ALL SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN 0.80 (E.G., COATED PER PR5-33-12 (FLAT BLACK)). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEMICAL FILM.
7. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
8. PROVIDE A ø.35 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #8 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO TOP OF BOX.
9. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS PER PR12-6-0103 WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATOR AND .18 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

INTERFACE CONTROL DRAWING

TRW
HSI POWER CONVERTER ELECTRONICS
E 11982 305651

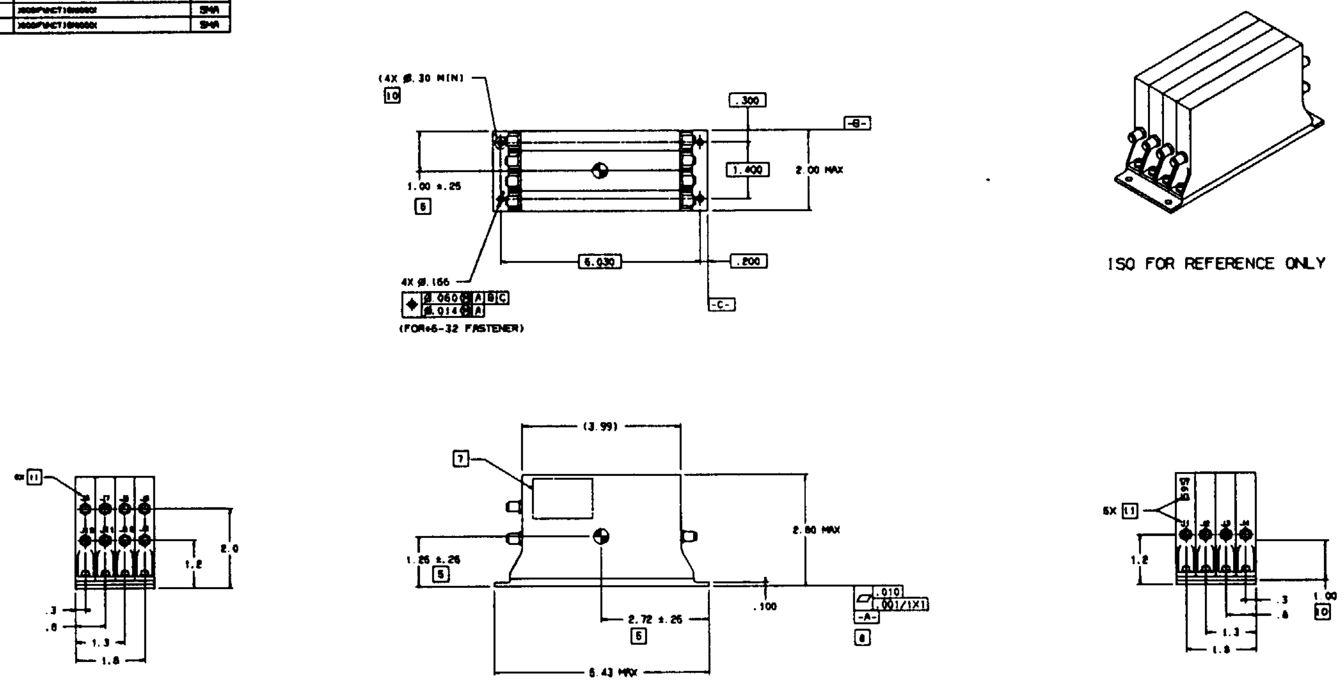
SST1 PR12-6 EQXXXXX PR12-3

CATIA

TRW			APPROVED SOURCES OF SUPPLY			APPLICATION	
DASH NO.	APPL SPEC	CAGE CODE	PART NO.	DWG OR DOCUMENT NO.	NAME & ADDRESS	USED ON (PROJECT)	NEXT ASSY
-1	EQX-XXXX	XXXXX	F304811-1	F304811	[illegible]	SST1	306696

CONNECTOR DATA

REF DES	CONNECTOR PART #	FUNCTION	TYPE
J1	TBD	XXXXFUNCTIONXXXX	SMA
J2	TBD	XXXXFUNCTIONXXXX	SMA
J3	TBD	XXXXFUNCTIONXXXX	SMA
J4	TBD	XXXXFUNCTIONXXXX	SMA
J5	TBD	XXXXFUNCTIONXXXX	SMA
J6	TBD	XXXXFUNCTIONXXXX	SMA
J7	TBD	XXXXFUNCTIONXXXX	SMA
J8	TBD	XXXXFUNCTIONXXXX	SMA
J9	TBD	XXXXFUNCTIONXXXX	SMA
J10	TBD	XXXXFUNCTIONXXXX	SMA
J11	TBD	XXXXFUNCTIONXXXX	SMA
J12	TBD	XXXXFUNCTIONXXXX	SMA



NOTES: UNLESS OTHERWISE SPECIFIED

1. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREIN IS APPROVED BY TRW REDONDO BEACH CALIFORNIA FOR USE IN THE APPLICATION(S) SPECIFIED HEREIN. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVIAL BY TRW OR NASA HEADQUARTERS.
2. IDENTIFICATION OF THE APPROVED SOURCE(S) OF SUPPLY HEREIN IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM DESCRIBED ON THIS DRAWING.
3. UNIT WEIGHT SHALL NOT EXCEED 0.86 LBS.
4. UNIT DISSIPATED POWER SHALL NOT EXCEED 1.0 WATTS PEAK.
5. INDICATES THE ESTIMATED LOCATION OF THE CENTER OF GRAVITY.
6. UNIT SHALL COMPLY PER TRW DOCUMENT EQX-XXXX.
7. PART IDENT PER EQX-XXXX. LOCATE APPROXIMATELY AS SHOWN.
8. ALL EXPOSED SURFACES EXCEPT MOUNTING AND CONTINUITY SURFACES SHALL HAVE AN EMITTANCE GREATER THAN .80 (ANODIZE OR BLACK PAINT). THE MOUNTING SURFACE SHALL BE COATED WITH MIL-C-5541 CLASS 3 CHEM FILM.
9. CONNECTORS SHALL BE EQUIPPED WITH CONNECTOR SAVERS AND DUST COVERS.
10. PROVIDE A ⌀.30 MIN FLAT AREA ABOUT EACH MOUNTING HOLE FOR #6 WASHER/TOOL CLEARANCE EXTENDING FROM MOUNTING FLANGE TO SPECIFIED DIMENSION.
11. MARK APPROPRIATE REFERENCE DESIGNATOR CALLOUTS WITH .12 MIN HIGH CHARACTERS FOR CONNECTOR DESIGNATORS AND .16 MIN HIGH CHARACTERS FOR THE UNIT DESIGNATOR. LOCATE APPROXIMATELY AS SHOWN.

SOURCE CONTROL DRAWING

TRW

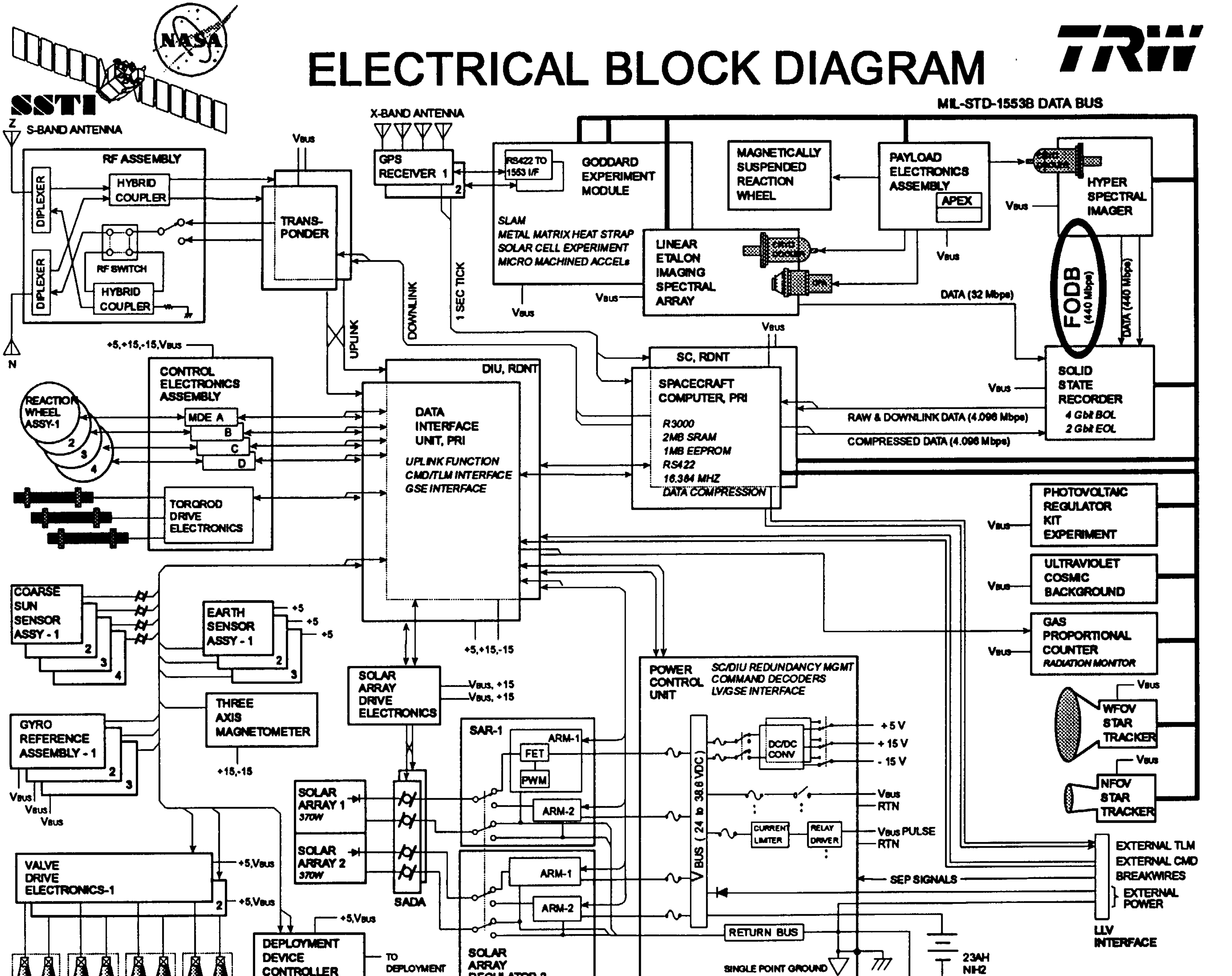
GPS QUAD PREAMP

E 11982 C305654

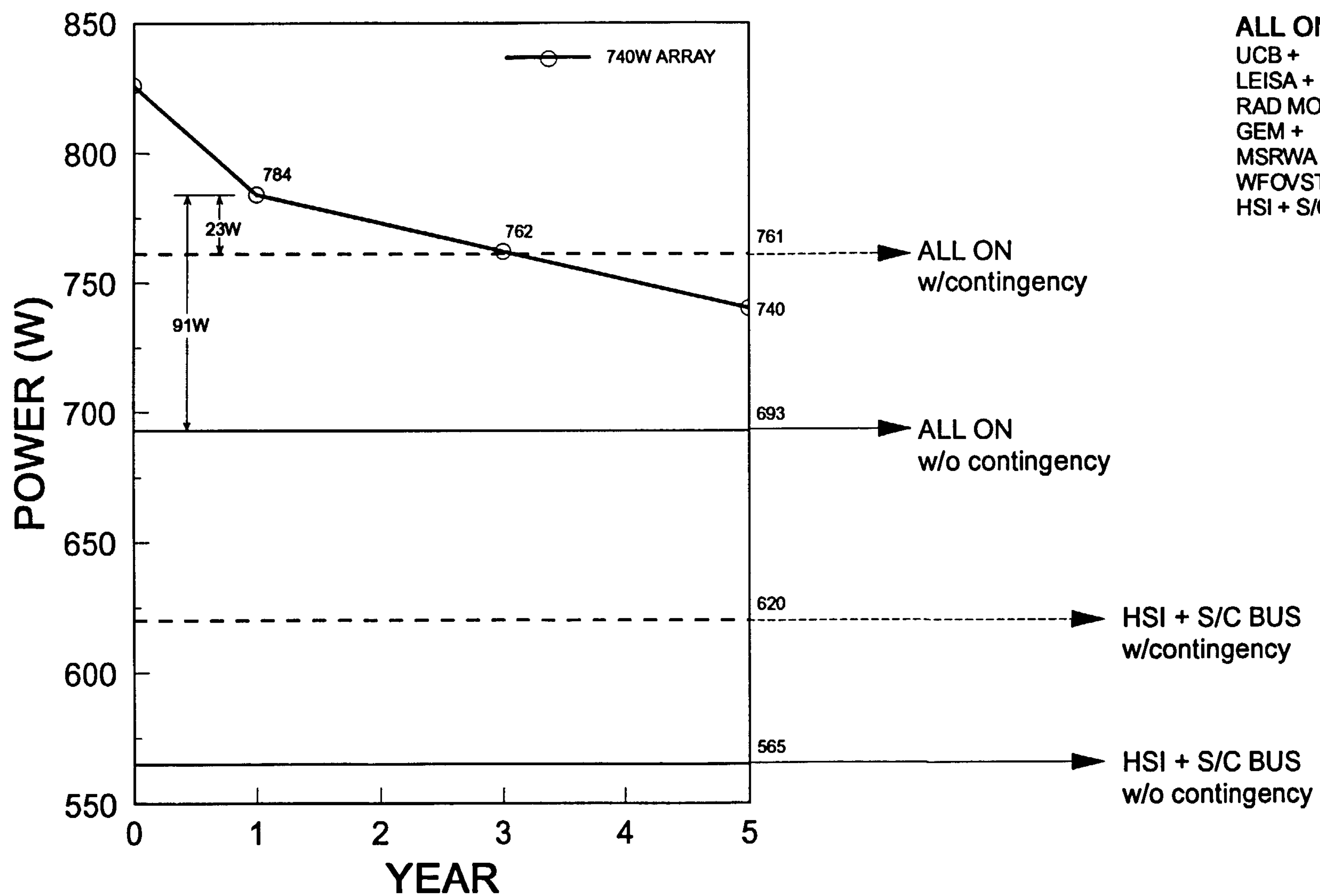
Electrical Design Integration

W. Jhang/D. Woods

ELECTRICAL BLOCK DIAGRAM



ARRAY OUTPUT vs LOAD



ALL ON =
UCB +
LEISA +
RAD MON +
GEM +
MSRWA +
WFOVST +
HSI + S/C

Power Budget (Watts)

SUBSYSTEM	SUNLIGHT AVE PWR	SUNLIGHT PEAK PWR	ECLIPSE AVE PWR	ORBIT AVE PWR	SAFEHAVEN AVE PWR
PAYLOAD INSTRUMENTS					
HSI	57.0	101.6	37.3	50.5	37.3
LEISA	19.5	19.5	19.5	19.5	19.4
UCB	13.8	13.8	19.2	15.8	11.3
PAYLOAD TOTAL	90.3	134.9	76.0	85.8	68.0
PAYLOAD SUPPORT EQUIPMENT	49.2	42.3	49.2	49.2	49.2
TECH DEMO	37.0	35.8	37.0	37.0	16.3
DATA MANAGEMENT/TT&C	60.8	56.9	60.8	60.8	60.8
GUIDANCE, NAV, & CONTROL	43.4	43.4	43.4	43.4	15.7
ELECTRICAL POWER & DIST	342.1	396.5	16.7	222.2	25.8
PROPULSION	42.5	42.5	40.8	41.9	61.6
THERMAL	15.5	15.5	3.5	11.1	14.6
GRAND TOTAL	680.8	767.8	327.4	551.4	312.0 (DOES NOT INCLUDE BATTERY RECHARGE POWER)

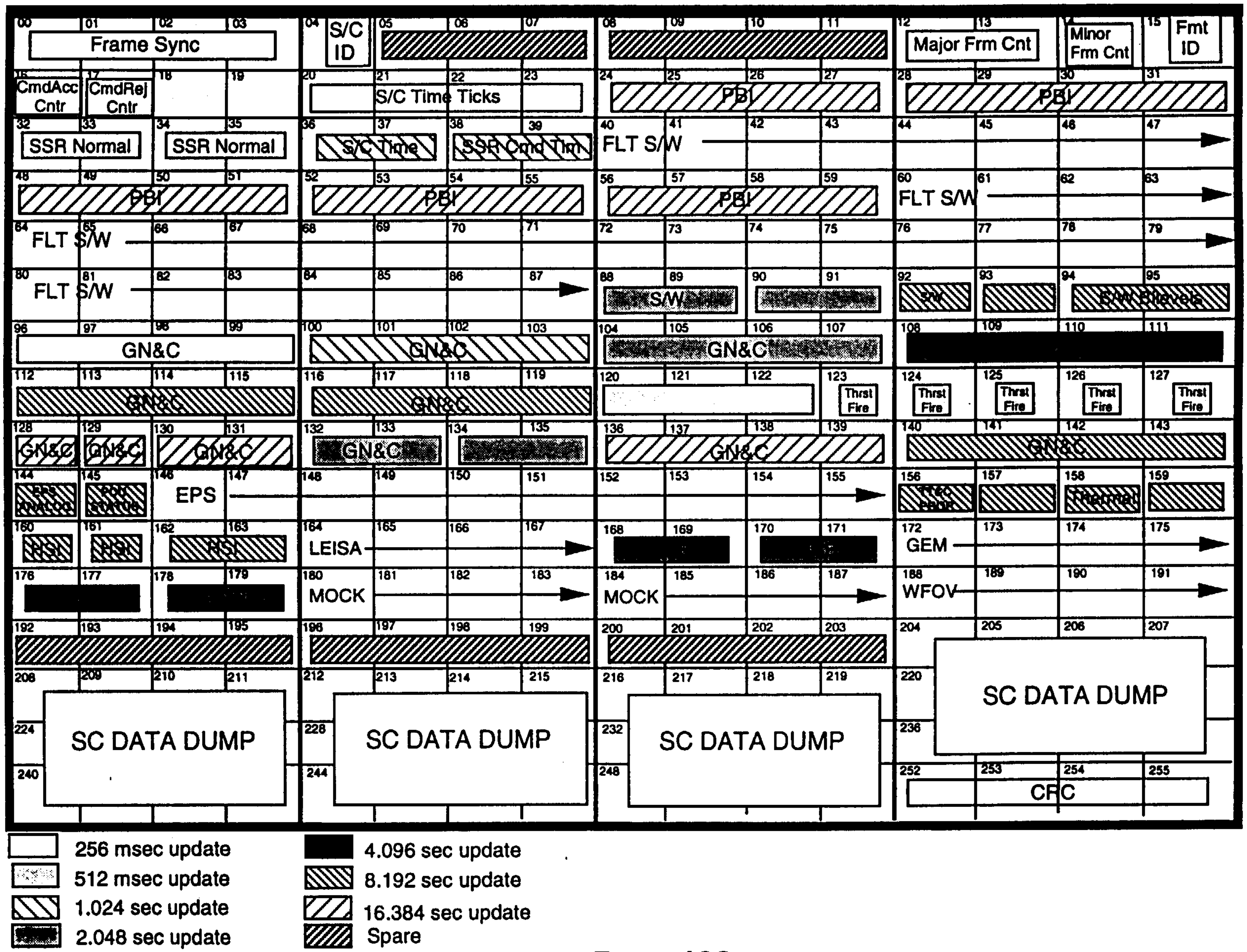
Peak power number assumes:

1. HSI is ON, UCB in standby.
2. XMTR off, 1553/FODB interfaces on, propellant heaters cycled on.
3. All other equipment in minimum operating mode.
4. Battery in full charge.

Launch/Ascent Power Profile
(T-1 to T+35 min)

Launch Loads	Watts
– S/A Regulators	4.3
– PCU	5.9
– Gyros	21.3
– Command Receivers	7.6
– Computer	38.6
– Pressure Transducer	0.5
– SLAM	16.7
– GEM	7.0
– SSR	21.1
– DIU	9.5
– Harness	2.6
– Margin (10%)	13.5
	148.6 (5A @ 30V)

NORMAL TFT *draft*



CMD/TLM SPARE CAPABILITY (DIU)

	COMMAND							TELEMETRY						
	BILEVEL		PCU RELAY	28V PULSE	SERIAL	ANALOG	SPECIAL	BILEVEL	SERIAL DIGITAL	ANALOG				
	BP	BL								ACTIVE	SUN SENSOR	AD590	Thermistor	SADA
USED	5	15	60	46	9	4	7	42	20	67	4	32	5	8
CAPABILITY	16	17	67	48	9	4	10	48	20	80	4	32	6	8
SPARE	11	2	7	2	0	0	3	6	0	13	0	0	1	0

67 relays
(51 HV + 16LV)

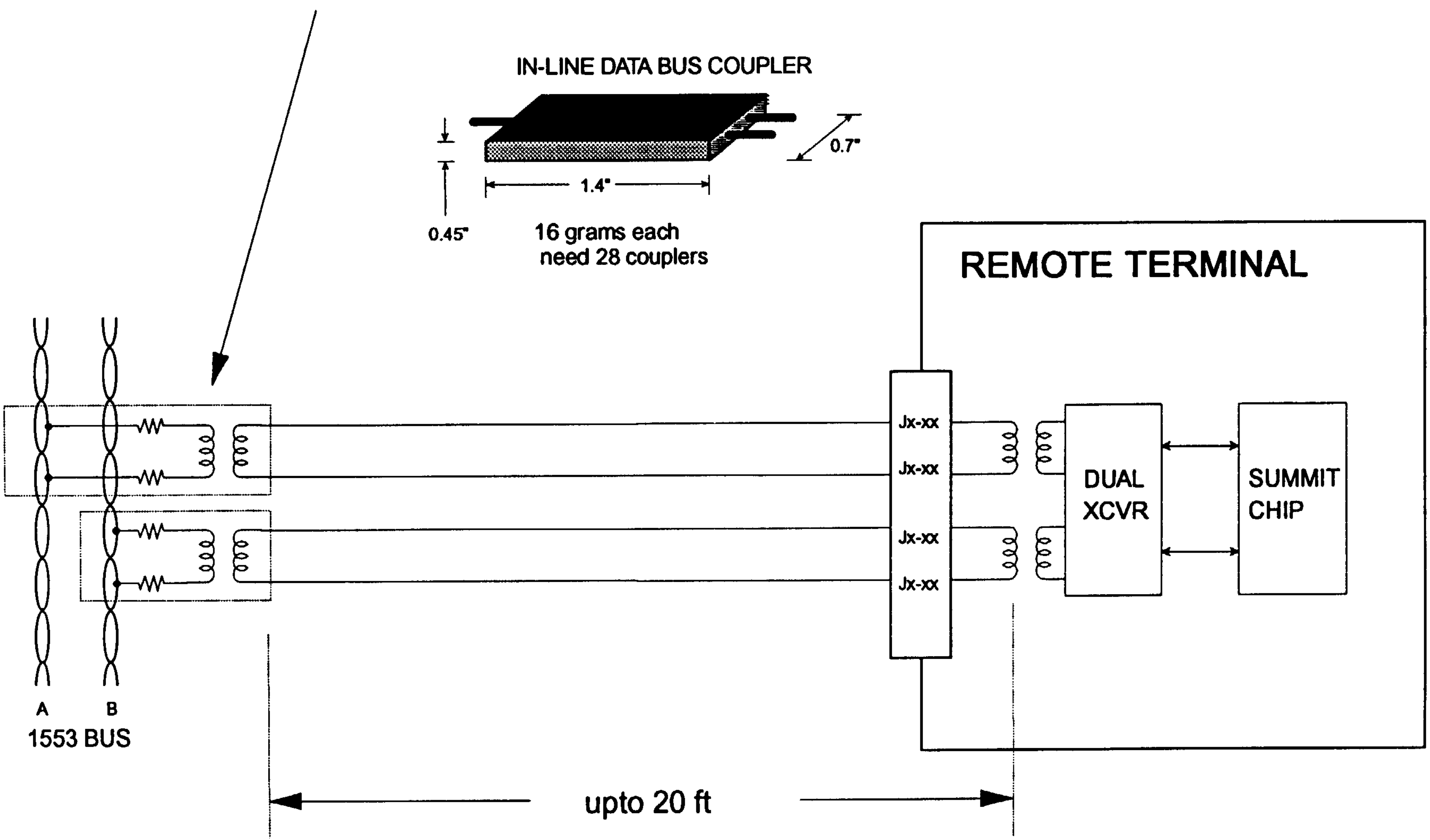
7 relays
(2 HV +3 SS+ 2LV)

2 for SAR
2 for PCU
2 for DDC
1 for VDE
2 for SADE

4 for SAR
2 for PCU
2 for DDC
12 for GRA

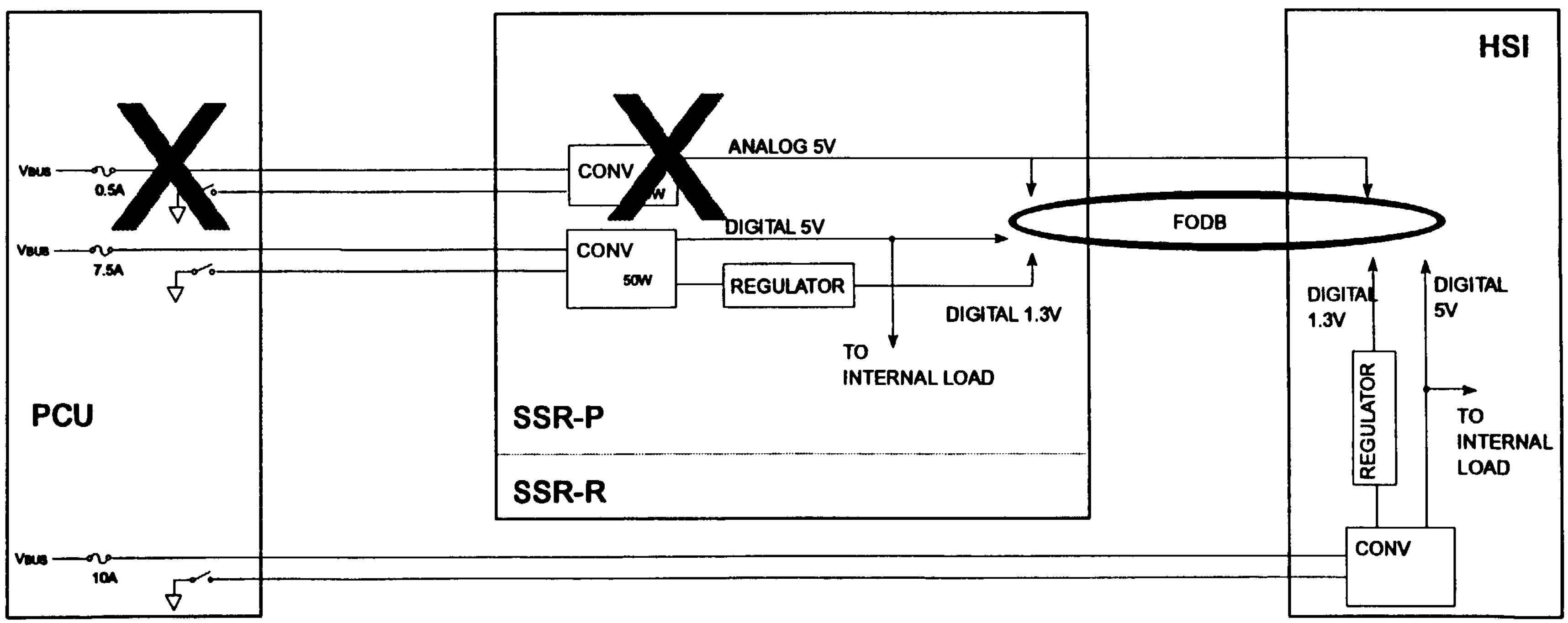
1553 INTERFACE

TRANSFORMER COUPLED



FODB POWER

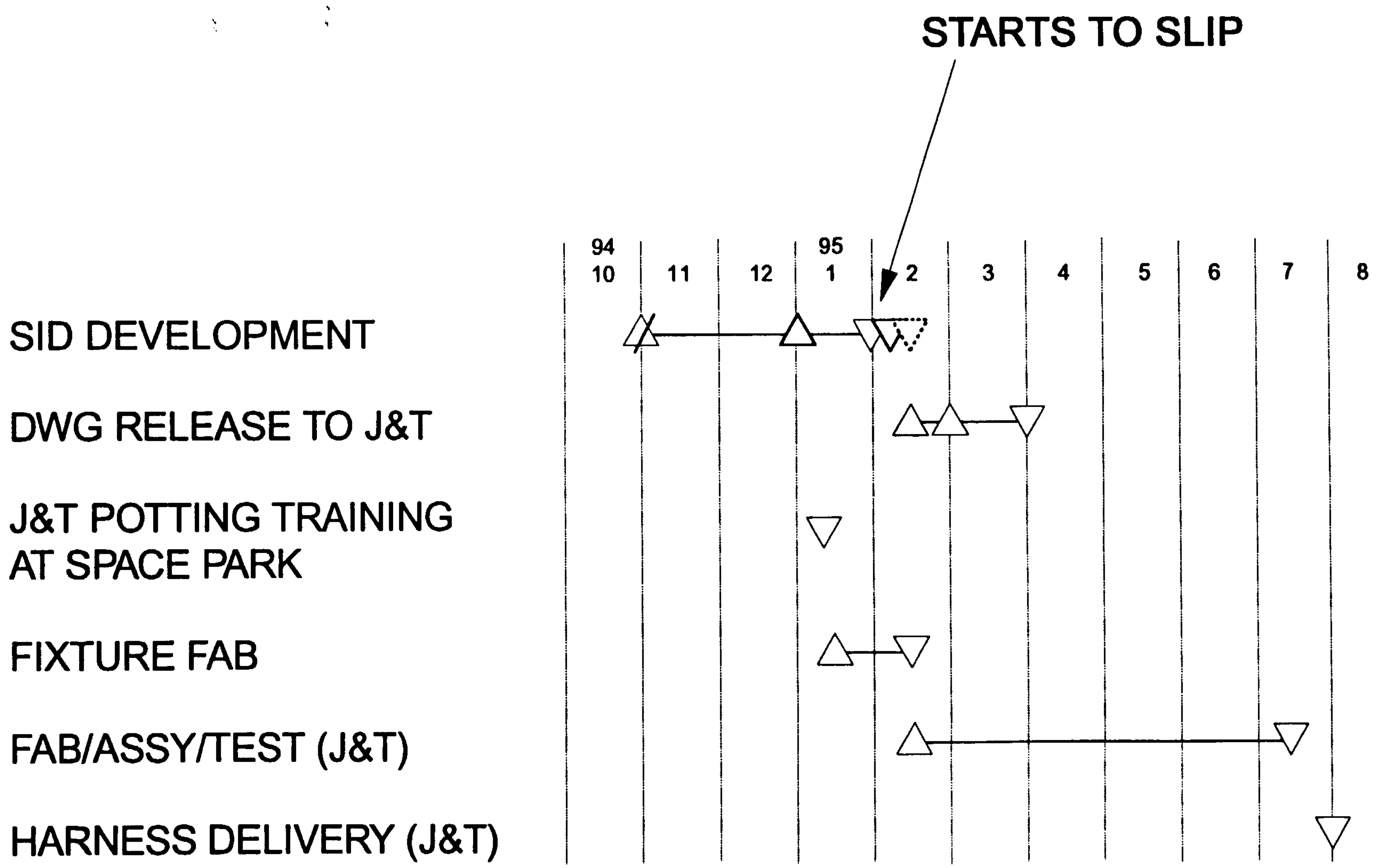
- NO NEED FOR SEPARATE ANALOG +5V
- SSR POWERS ITS CFBIU AND FBIU
- HSI POWERS ITS FBIU



Harness Status

- Preliminary Harness interconnect diagram generated
  - Connector count - 257 DC and 35 RF
- Most pinouts have been received, some are preliminary
- Need pinout information for:
  - Battery
  - SSR
  - HSI
  - Transponder
  - RF Assembly
  - Heaters and Thermistors
- SID activity has started

HARNESS SCHEDULE



EDI STATUS

- Fuse Requirements Document published
- Power Allocation Document released to CADM
- Preliminary Comand Allocation Document revised
- Preliminary Telemetry Allocation Document revised
- Magnetic Moment Analysis performed
  RSS total = 0.532 A-m^2

- Remaining Tasks
  - Finish SID
  - Generate TFTs
  - Release CAD and TAD to CADM
  - Publish Electrical Interface Spec
  - Support I&T

SPACECRAFT INTEGRATION, TEST, & LAUNCH

System Integration & Test
(See Handout)

B. Brooks

SPACECRAFT INTEGRATION, TEST, & LAUNCH

Launch Interface & Operations

D. Turner/R. Desilets

LAUNCH
INTEGRATION AND OPERATIONS

CDA OUTLINE

- Reminders and Actions from ICDA #2 . . . . Turner
- Assessment of Major TRW and LSMC Milestones . . . . Turner
- TRW & LMSV Roles and Responsibilities . . . . Turner
- Launch Processing Facility Decription . . . . Turner
- Launch Processing Payload Integration & Test Flow . . . . Turner
- SV-to-LV ICD Development . . . . Desilets
- Range Safety Considerations and Concerns . . . . Turner

TRW

REMINDERS(R) & ACTIONS(A) FROM ICDA #2:

1. (R) IS RANGE SAFETY WORKING WITH LOCKHEED TO DEVELOP LAUNCH PROCESSING?

ANS. LOCKHEED IS THE PRIMARY INTERFACE WITH THE RANGE FOR LV AND SV SAFETY CONCERNS AND ISSUES. TRW MUST SATISFY THE REQUIREMENTS OF WRR 127-1 AS NEGOTIATED BY LMSC WITH THE RANGE FOR COMMERCIAL LAUNCHES FROM VAFB.

COMMERCIAL LAUNCHES FROM VAFB ENJOY SOME RELIEF FROM THE STRINGENT USAF SAFETY REQUIREMENTS FOR BOOSTERS; HOWEVER, LMSC IMPOSES 127-1 REQUIREMENTS ON THE SV PRODUCERS AT THIS TIME.

2. (A) CAN COMMANDS BE SENT TO SSTI *SLAM* EXPERIMENT THROUGH THE BOOSTER?

ANS. LOCKHEED WILL ENTERTAIN A REQUIREMENT FOR BOOSTER INTERACTION WITH THE *SLAM* PAYLOAD DURING COUNTDOWN. IT WILL BE AN OPTIONAL SERVICE AND MUST BE PRICED SEPARATE FROM THE STANDARD SERVICES. (IT IS LIKELY TO BE EXPENSIVE—ed.)

LV INTEGRATION - 01/18/94

ASSESSMENT OF MAJOR TRW AND LSMC MILESTONES:

	COMPLETE	COMMENT
Key Contract Documents Milestones		
Launch Services Requirements Document	In Negotiation	
Preliminary Payload-to-LV Icterface Control Document (ICD)	Feb 01	TBR Jan 31
Final Payload-to-LV Interface Control Document (ICD)	Jul 01	
Lockheed LLV1 Hardware & Milestones		
Payload Adapter Design/Procure/Fab	Jun 15	
Fairing Design/Procurement/Fab	Jun 15	
LLV1 CDR	Jun 01	
Vandenberg Range Milestones		
Program Introduction Document (PI)	Apr 05	
SSTI Program Requirements Document (PRD)	May 05	Prelim. Del. Nov 1994
Deliver System Safety Program Plan (ARAR)	Apr 03	Prelim. Del. Oct 1994
DoT License Application	Jul 05	
Hazardous Operations Procedures	1996 Mar 10	
Payload Environmental Assessment	1996 May 05	
Dot License Issued	1996 May 05	

MAJOR TRW AND LSMC MILESTONES (CONCLUDED):

	COMPLETE	COMMENT
TRW Technical Data and LMSC Supporting Analyses		
TRW Deliver Initial Spacecraft Mass Properties	1994 Nov 11	
LMSC Preliminary Trajectory Analysis	1995 Jan 20	
TRW Deliver Initial Spacecraft Dynamic Model	Jan 03	
LMSC First Coupled Loads Analysis	Mar 01	
TRW Deliver Spacecraft Thermal Model	Jan 03	
LMSC Thermal Analysis	Feb 15	
TRW Deliver Spacecraft Acoustic Model	Feb 15	
LMSC Acoustic Analysis	Mar 15	
TRW Deliver Spacecraft Transmit Frequencies	Mar 15	
LMSC RF/EMI/EMC Evaluation	May 03	
TRW Deliver Updated Spacecraft Mass Properties	Apr 15	
LMSC Updated Trajectory Analysis	May 15	
TRW Deliver Updated Spacecraft Dynamic Model	Aug 01	
LMSC Second Coupled Loads Analysis	Oct 01	

LV INTEGRATION - 01/18/94

RESPONSIBILITIES:

TRW	LMSC
• Provide to LMSC SSTI payload requirements for VAFB Range services: transportation and escort, hazardous waste disposal, RF "fuzz busters," photography, personnel access, etc.	• Provide leadership for Range interfaces: SV and LV safety reviews, SV and LV Range support requirements, launch readiness.
• Provide to LMSC SSTI payload safety documentation (Accident Risk Assessment Report).	• Coordinate all mission safety compliances with VAFB Range Safety.
• Prepare launch site payload processing procedures: nominal and contingency.	• Assure Integrated Processing Facility (IPF) is prepared for SV operations.
• Support and participate in all reviews: MRR, LRR, etc.	• Coordinate, maintain and publish launch site master schedule.
• Coordinate with LMSC in preparation of launch site program schedules& operations.	• Coordinate daily status meetings: management and schedule reviews.
• Process SV and perform functional tests; provide hydrazine fueling procedure.	• Perform SV hydrazine fueling with TRW assistance.
• Coordinate with LMSC in preparation of countdown timeline and GO/NO-GO decisions.	• Provide payload access through umbilical and conduct countdown operations.

LAUNCH PROCESSING FACILITY DESCRIPTION:

- All processing for the SSTI *Lewis* launch will be conducted at Space Launch Complex 6 (SLC-6) at VAFB (Figure 1).

- The only payload to be processed to date in the SLC-6 facility, other than pathfinders, is the USAF/TRW Space Test Experiments Platform (STEP) Mission 0, launched on March 13, 1994; arrived December 12, 1993.

- Payload processing facilities (Figure 2) comprised of • a Class 100,000 30x100 cleanroom entry Airlock, • a 30x146 Class 100,000 Transfer Isle connected by positive pressure roll-up door to the Airlock, • three 35x44 payload Erection Checkout Cells, • personnel work areas, and • large storage areas in the building.

- EGSE to support SSTI *Lewis* depicted in Figure 3. Exact location TBD.

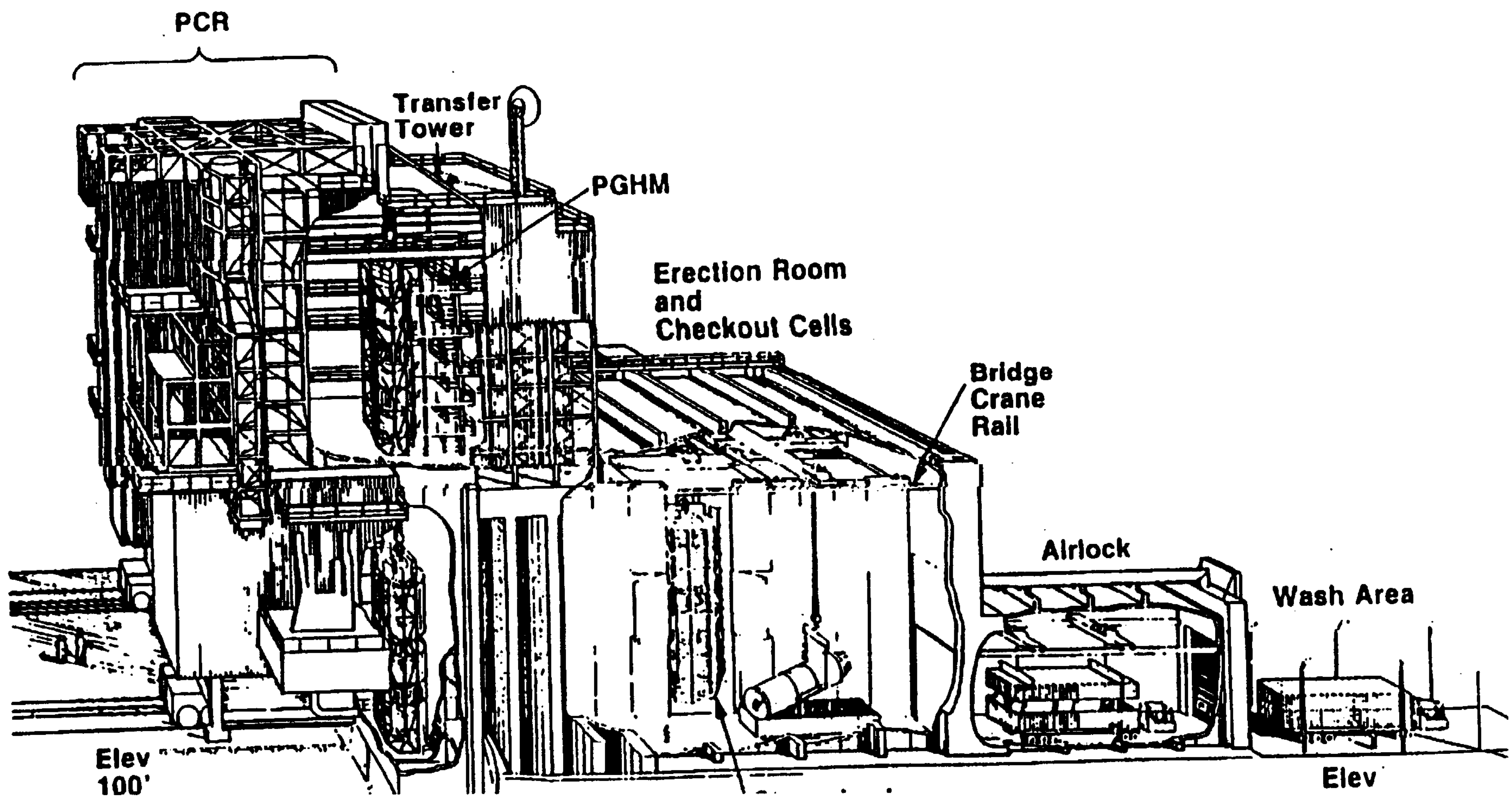


Figure 1. VAFB Space Launch Complex Six (SLC-6) PIF.

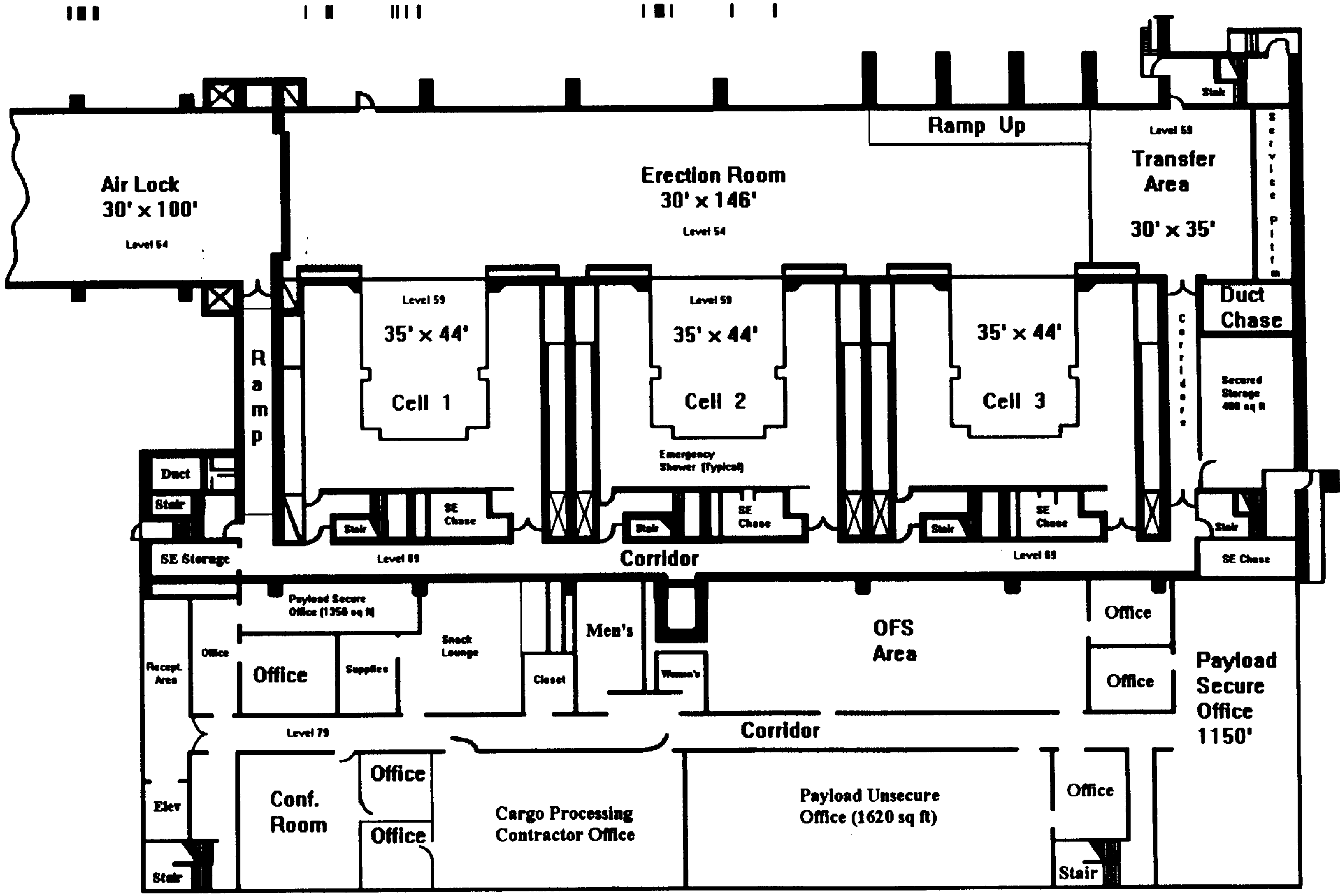


Figure 2. SLC-6 Payload Integration Facility (PIF)

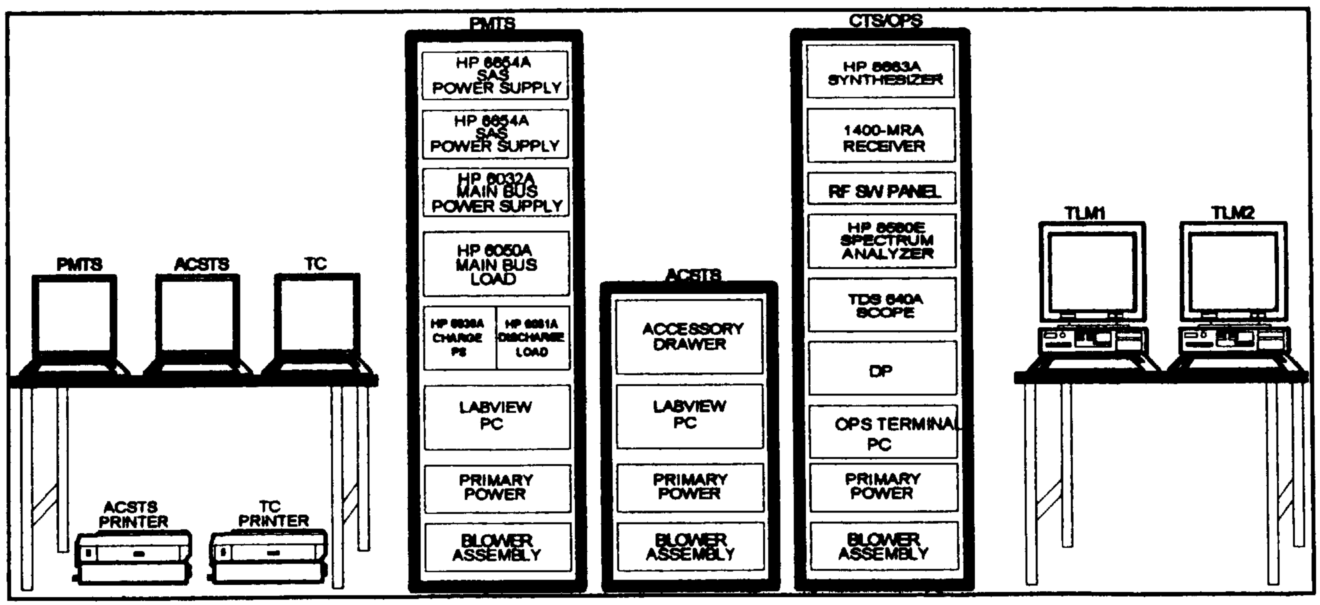
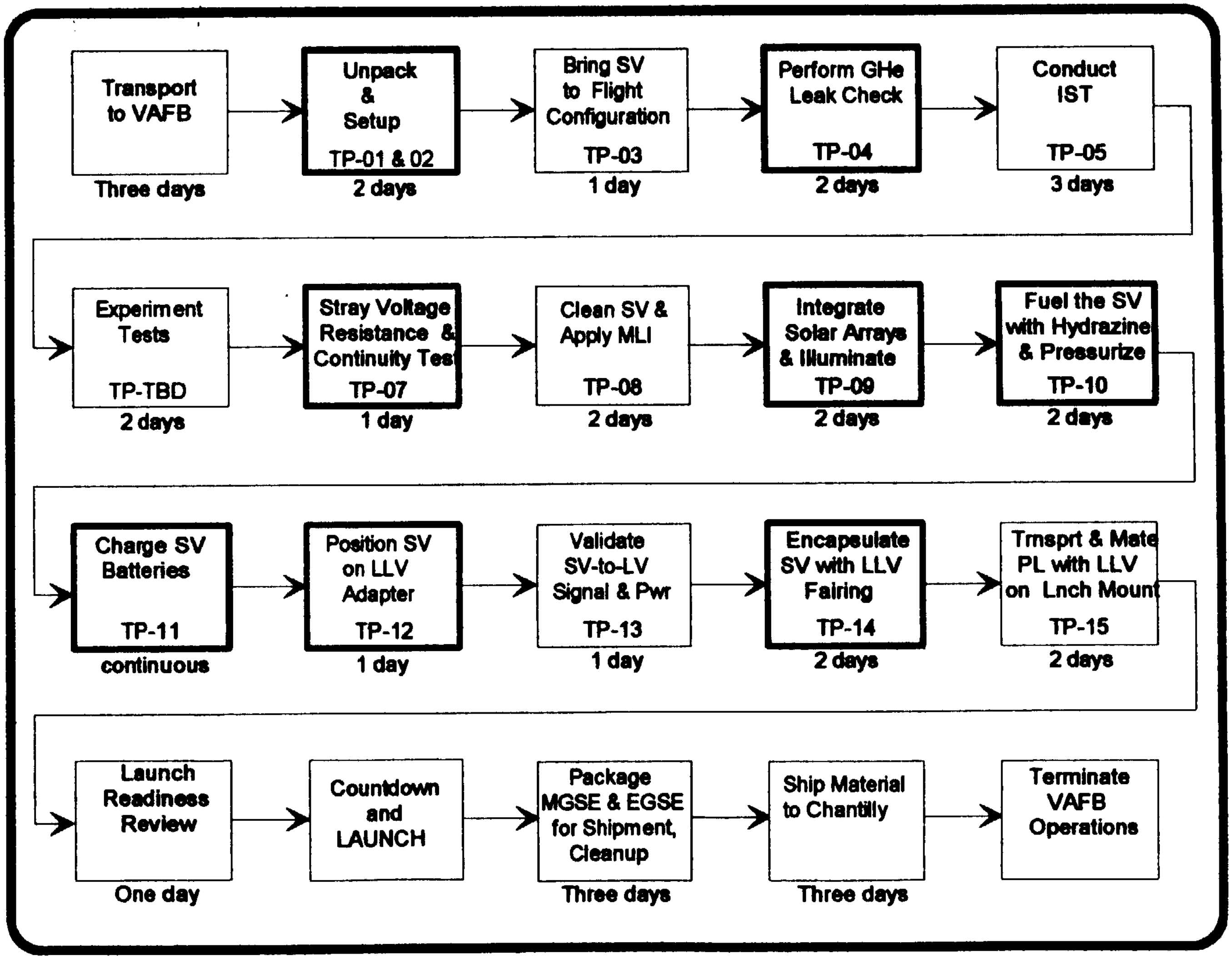


Figure 3. SSTI *Lewis* EGSE Definition

LV INTEGRATION - 01/18/94

PAYLOAD LAUNCH PROCESSING FLOW CHART:



LAUNCH BASE SV PROCESSING PROCEDURES:

ID	DESCRIPTION	TIME
TP-01	*Off-load Transport Vehicle at VAFB Integration Building*	1 day
TP-02	*Prepare MGSE, EGSE, and SV for Operations*	1 day
TP-03	*Bring SV to Flight Configuration*	1 day
TP-04	*Perform Propulsion System GHe Leak Check*	2 days
TP-05	*Perform Integrated Systems Tests*	3 days
TP-TBD	*Perform Experiment Tests*	2 days
TP-07	*Perform Deployment Stray Voltage and Continuity Checks*	1 day
TP-08	*Clean SV and Apply Multilayer Insulation*	2 days
TP-09	*Integrate Solar Arrays and Perform Illumination Tests*	2 days
TP-10	*Fuel the SV with Hydrazine*	2 days
TP-11	*Charge SV Flight Batteries*	Intermittent
TP-12	*Configure SV for LV Mate and Position on I/F Adapter*	1 day

LAUNCH BASE SV PROCESSING PROCEDURES (continued):

ID	DESCRIPTION	TIME
TP-13	*Check SV-to-LV Signal/Electrical Connections*	1 day
TP-14	*Encapsulate SV with LV Fairing*	2 days
TP-15	*Transport and Mate Payload with LV*	2 days
TP-16	*Use of Rack-Mounted and Portable Hydrazine Sniffers*	Intermittent
	TOTAL WORK DAYS:	23 DAYS

LAUNCH BASE CONTINGENCY PROCEDURES:

CP-01	*Off-load Hydrazine During Fueling Operations*	N/A
CP-02	*Off-load Hydrazine Before Encapsulation*	N/A
CP-03	*Off-load Hydrazine After Encapsulation* (Figure 5.)	N/A
CP-04	*De-Integrate and Safe the SV*	N/A
CP-05	*Servicing the SV after a Launch Abort*	N/A

LAUNCH BASE CREW SIZE AND RESPONSIBILITIES:

Management Crew	Size	Duration
• Launch Integration Manager	1	entire
• Test Director	1	entire
Propulsion Crew		
• Leak Check Team	2	3 days
• Fueling Team	2[1]	3 days
IST Crew		
• Test Engineers	2	9 days
• Experiments Team	?	3 days
Mechanical Engineers		
• Setup and Maintenance	2	entire
• QA Specialists	1	entire

[1] Test Director and SV Fueling Observer (in SCAPE).

Spacecraft-to-LLV ICD Development

SSTI

Status and Issues

TRW

<u>Status - General</u>

- LMSC has lead for ICD development
- Draft ICD material has been provided as input to LMSC
- LMSC draft due for review 1/31/95
- A number of issues presently in work
  - Some interface issues to be incorporated into contract Launch Services Requirements Document(LSRD)
- Next MIWG at VAFB 1/31/95 & 2/1/95
  - Program introduction to 30SPW (formal UDS inputs later)
  - Safety review
  - ICD review
  - SLC facility familiarization

SSTI

Status and Issues (continued)

TRW

Status

- Launch mass of Lewis spacecraft is 850.0 lb maximum (LSRD)

- Injection conditions (LSRD)
  - Altitude: LMSC may offer higher altitude than contractural 300 Km circular
    - need to define altitude
    - 300 Km is our minimum, anything higher is better
    - can't trade higher altitude for spacecraft weight—yet
  - Tipoff rates (residual angular rates, any axis):
    - 2 °/sec max about any transverse axis and the longitudinal axis
    - Separation velocity is tipoff limit-dependent; will be left for ICD

- Adaptor bolt circle diameter : Reduce from 38.81 in. to 37.15 in. (LSRD)
  - Exploits LLV optional capability to save bus weight

- Fairing access (LSRD)
  - One door to be provided;
  - Spacecraft clocking to accomodate best launch stand access

SSTI

Status and Issues (continued)

Issues

- Injection conditions (LSRD)
  - inclination: LMSC bid to RFP value <0.1° 3σ,
    - •• LMSC resisting original <0.06° 3σ quote waiting for DLV flight performance results
    - •• fuel weight impact for CDA - expect eventual fuel margin increase

- Cooling air to battery radiator
  - TRW has reduced power dissipation requirements
  - cooling design in work @ LMSC

- Early power-up of Utility Room at launch site
  - Current plan calls for power up approx. 4 hr after disconnect of GSE
    - •• Spacecraft on internal power alone
  - LMSC working relevant safety issues to allow early power-up
  - Goal is procedural solution with no design impact to spacecraft

- Substitute helium for nitrogen propulsion system pressurant
  - LMSC expects to easily accomodate

Status and Issues (continued)

<u>Issues (continued)</u>

- LMSC offer to provide series of SLAM discretes during flight, tied to stage events
    - Cost issue TBD
    - TRW evaluation vs planned operation of SLAM TBD

SSTI

Interface Verification Process

TRW

- Interface verification matrix will incorporate items contained in
  - Launch System Requirements Document (LSRD) - to be finalized soon
  - Interface Control Document (ICD) - first review 1/31/95
- Each ICD item requires verification
- Verification methods will include, as appropriate for each item
  - Analysis
  - Test
  - Delivery
  - Analogy
- Matrix and verification methods to be reviewed and approved by TRW
  - First draft expected for review at preliminary ICD meeting 1/31/95

LV INTEGRATION - 01/18/94

30 SPW RANGE SAFETY CONCERNS:	TRW RESPONSE:
● Spacecraft computer safety:	● Mechanical open circuit (IFJ) control: thruster valve, iso valve, NEI.
● Inadvertent solar array deployment:	● Two independent electrical inhibits to power for NEIs.
● Reaction or scan wheel disintegration:	● Insufficient power to over-drive wheel or circuits two-fault tolerant.
● Non-ionizing RF radiation:	● Single-fault tolerant if radiation is > 5 Mw/Cm^2 without antenna hat.
● Ionizing radiation (experiment):	● Protective covers while personnel are present; area evacuated for testing.
● Battery removal controls after propellant is loaded:	● System single-fault tolerant. Propellant must be removed before battery removal.

LV INTEGRATION - 01/18/94

LAUNCH SITE SV TESTING:

Integrated Systems Tests

- ADACS and Propulsion Subsystem operation
- Deployment device circuits
- RF Subsystem for command and control
- Power conditioning and supply circuits
- Data management system operations
- Experiment field tests

Verify Communication Capability

- STDN coax cable radiation from SV antenna to EGSE rack
- Validate receive and command capability from EGSE

Verify SV-to-LV Interfaces

- Pyro commands to V-band bolt cutters
- Power and signal functions through separation connectors
- Safety telemetry to Launch Vehicle Control Van

Propulsion Subsystem Leak Check

- Gaseous helium pressure check of tank, lines, thrusters

30 SPW RANGE SAFETY CONCERNS:	TRW RESPONSE:
● Overheating propellant:	HEATER FAILURE ● Heater circuits two-fault tolerant. ISO VALVE FAILURE ● Pre-Launch: ISO valve power two-fault tolerant. PRESSURE TRANSDUCER FAILURE ● Circuit two-fault tolerant.
● Inadvertent firing of thrusters: [See Note 1.]	PRE-LAUNCH (ISO VALVE CLOSED) ● Electrical controls single-fault tolerant. PRE-LAUNCH (ISO VALVE OPEN) ● Electrical controls two-fault tolerant. ● Ability to close ISO valve if liftoff is aborted.

Note 1: Three independent electrical inhibits shall be provided to prevent application of power to the three valves that prevent full pressure thruster firing. Provision shall be made to exhibit the position of the electrical inhibits and valves at all times up to liftoff.

PAYLOADS & TECHNOLOGY DEMONSTRATIONS
Overview

D. Conte

PAYLOAD AGENDA

- Overview

- Primary Experiment Summaries
  - Hyperspectral Imager (HSI)
  - Linear Etalon Imaging Spectral Array (LEISA)
  - Ultraviolet Cosmic Background Spectrometer (UCB)

- Technology Demonstration Briefs

PAYLOAD SUMMARY

- Good To Excellent Progress In All Experiments And Technology Demonstrations
- Commendable Cooperation And Communication Among Team Members
- Schedules Tight
- No “Show Stoppers”
- Finalizing Interface Agreements

PAYLOAD STATUS

- Emphasis On ICDs and MOUs Since ICDA#2; Good progress.
- HSI In Detailed Design/Fabrication
  - Procurement Actions Completed For Purchase Of Optical & Optomechanical Components And Sensors
  - Upgrades For 5-yr Life Included
- Performing Final Thermal Analysis For HSI And LEISA
  - Performing Final Cryocooler Characterization Tests Prior To Shipment To LEISA
- UCB On Schedule; Spectrograph Front End and Mechanical CRDs Complete
- Lossy Data Compression Tests Show Good Results (CR $\geq$ 50)
- DCM Investigating Board Fabrication Alternatives (Navy) As A Schedule Hedge

SSTI

PAYLOAD STATUS
(2 of 4)

TRW

- Plan For GPS Upgrade Finalized
  - Will Fly Redundant Space-Qualified Loral Tensor Receivers
  - Procurement In Progress By GSFC

- GEM Interfaces Defined
  - GSFC Internal ICDs Developed
  - ASCE Electronics Board Design Initiated Through J & T (Services All Solar Cell Experiments)

- Metal Matrix Heat Strap Experiment Plan Revised, Reducing Heater Power Requirement From 36W To 2W

- Successful RIM Design Audit Held 1/11/95

- Micromachined Accelerometer Interface With GEM Defined

PAYLOAD STATUS

(3 of 4)

- GPC On Schedule
- New Cloud Editing Algorithm Added To Detect High Altitude Clouds; Excellent Progress Toward Obtaining Approval For Use Of RTNEPH Cloud Cover Resources
- WFOV Star Tracker Design Completed
- Magnetically Suspended Reaction Wheel In Operation At TRW Lab
- MOCK Software Interfaces Defined
- Enhanced ACS Software Interfaces Defined
- FEM Provided To On-Orbit Identification And SLAM Principal Investigators For Analysis Of Spacecraft Structural Response

SSTI

PAYLOAD STATUS
(4 of 4)

- PEA Electronics Design Completed; PEA Being Utilized To House APEX

- OPA Available For Test

- Plans For Addition Of Three Small Technology Demos In Progress
  - Photovoltaic Regulator Kit Experiment (PRKE) From NASA Lewis Research Center Demonstrates Low-Cost Solar Array Regulator For Lightsats
  - Advanced Packaging Experiment (APEX) From Jet Propulsion Lab/TRW Demonstrates MCM Implementation Of RH-32 Processor
  - Packaging Experiment From Phillips Lab (PLEX) Demonstrates MCM Implementation Of RAD6000 Processor

OPEN ITEMS
(1 of 2)

- LEISA Thermal Management Analysis/Design
- GEM Housing Weight
- Metal Matrix Heat Strap Radiator Location
- SLAM and Micromachined Accelerometer Sensor Locations
- Amorphous Solar Cell And GaAs Cell Layouts (Cascade GaAs Cell Location Determined)
- Calibration Technique For GPS Attitude Determination Experiment
- DCM Board Fabrication Technique (Multilayer vs. Microwire)
- R-3000 Breadboard For DCM Development

OPEN ITEMS
(2 Of 2)

- Launch Vehicle Initiation Signal And Final LLV Timeline For SLAM Data Collection
- Hybrid Delivery Schedule For FODB Interfaces
- Dual Port RAM Delivery To LEISA And DCM
- Provide Final GPS Data Definitions and Functional Call Information To MOCK
- HSI and LEISA Radiance Sensitivities For Cloud/Feature Editing

ICD STATUS

EXPERIMENT	Outline Only	Partial Data	Key Data	Ready to Sign	Signed	Comments
HSI				X		
LEISA					X	Signed by PI; in TRW cycle
UCB				X		
GEM			X			Expect Ready To Sign version this week
Metal Matrix Heat Strap			X			Awaiting finalization of radiator location
Rad Monitor (GPC)					X	
SLAM				X		Sensor locations being selected
Solar Cell			X			Awaiting final cell selection, mounting, and wiring details
GPS Att Det			X			New Tensor receiver
Data Comp					X	Signed by PI; in TRW cycle
WFOV				X		
RIM (Eq Spec)				X		Several TBDs, but no issues
Enhanced ACS			X			Expect Ready-to-Sign version this week
MOCK				X		
MSRW				X		
PEA				X		
Cryocooler			X			

MOU STATUS

- GSFC MOU
  - Signed! Signed! Signed!
  - Letter Sent To NASA/HQ Requesting Release Of Funds To GSFC
    - > $100k For GPS Withheld Pending Definitization Of ECP
    - > Expecting ECP Definitization By End Of Month
- LaRC MOU
  - MOU Body And Revised Attachments Submitted To LaRC
  - Awaiting Comments From LaRC Legal Office
- LeRC MOU (Photovoltaic Regulator Technology Demonstration)
  - Draft From LeRC Received By TRW
  - Requires Final Technical Review and Legal Review
- JPL MOU (RH-32 MCM Technology Demonstration)
  - Plan Modification/Attachment To Existing MOU

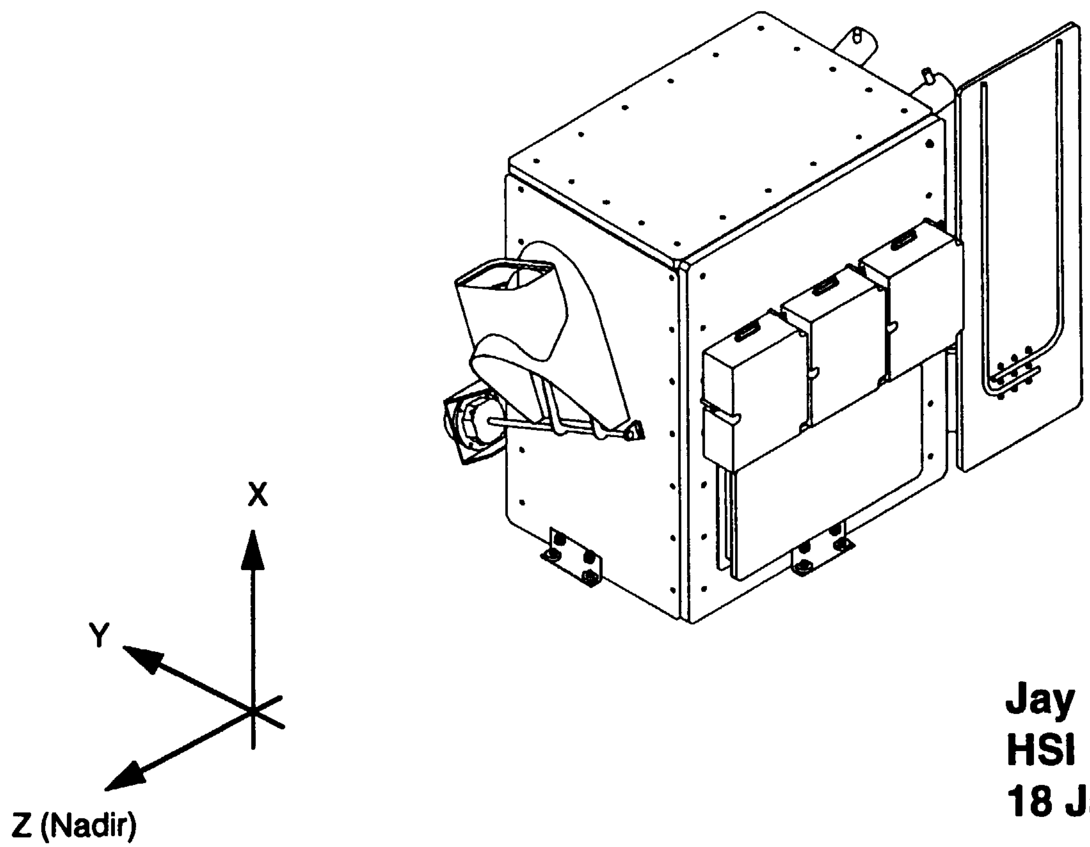
PAYLOADS & TECHNOLOGY DEMONSTRATIONS HSI

J. Marmo

SSTI

Hyperspectral Imager
CDA Status

TRW

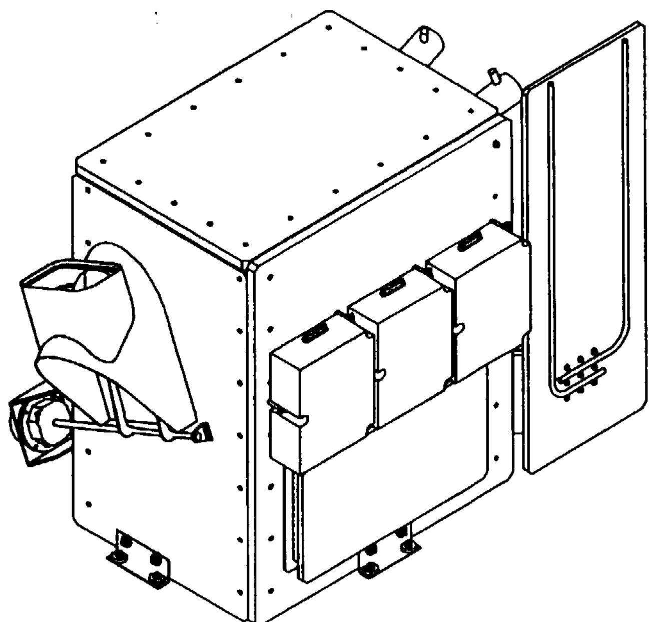


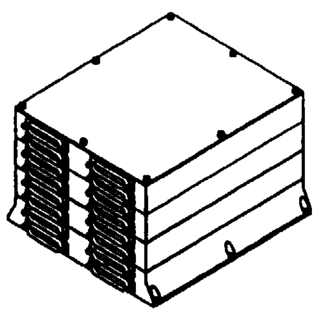
Jay Marmo
HSI Payload Manager
18 January 1995

CDA, 1

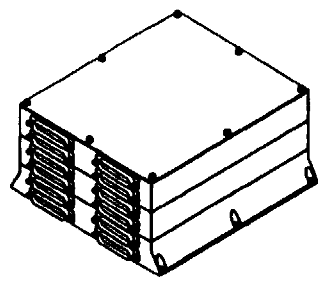
Hyperspectral Imager Summary

HSI Sensor Assembly (HSA)





HSI Control Electronics (HCE)



HSI Power Electronics (HPE)

- **Pushbroom scanned, body pointed imaging spectrometer and panchromatic camera**
  - 384 selectable bands, 0.4 - 2.5 μm
  - 5 m Pan, 30 m Hyperspectral (HS) Ground Sample Distance (GSD)*
  - 6% radiometric accuracy, 1σ, HS
- **In-flight calibration subsystem**
- **Pulse tube cryocooler with active vibration damping**
- **Weight - 32 kg****
- **Power - 51 W**, orbit avg.**
- **Data storage, compression, harnesses, etc. provided by spacecraft**

* @ nadir, 523 km altitude
** w/o contingency

CDA, 2

SSTI

HSI Requirements Summary
(SS31-002, HSI Payload Specification)

TRW

No.	Para.	Requirement	Capability	Verification Method
1	3.2.2.1	Volume Consistent with HSI ICD#IF31-003	Meets requirement	Inspection
2	3.2.2.2	Orbital Average Power ≤50.48 Watts*	50.55 Watts	Test
3	3.2.2.2	Safe Haven Power ≤ 37.25 Watts*	27.71 Watts	Test
4	3.2.2.2	Eclipse Average Power ≤ 37.25 Watts*	37.25 Watts	Test
5	3.2.2.3	Weight ≤ 31.3 Kg*	31.7 Kg	Inspection
6	3.2.3.1	On-orbit Life > 5years	Meets requirement	Analysis
7	3.2.3.2	Reliability >0.5 EOL (goal)	TBD	Analysis
8	3.2.1.2.1	Instantaneous Field of View 9.5±.5 μrad (pan), 57±3 μrad (HS)	Same	Test
9	3.2.1.2.2	Full Field of View > .55° (HS), > 1.1° (pan)	0.84° (HS), 1.42° (pan)	Test
10	3.2.1.2.4	MTF > 0.10 @50 cyc/mrad (pan), >.28 @ 8.3 cyc/mrad (HS)	0.13 to 0.18 (pan), 0.32 to 0.52 (HS)	Test
11	3.2.1.2.9	Boresight Drift < 20 arcsec (roll & pitch), < 100 arcsec (yaw)	< 17 arcsec all axes (TBR)	Analysis & Test
12	3.2.1.2.10	Jitter <8μrad @ 240 Hz, <2μrad @ 1440 Hz	TBD	Analysis& Test
13	3.2.1.2.5	Min Daily Data Quantity >1 Gbit	Meet requirement	Analysis
14	3.2.1.2.6	Longest Continuous Data Collect >30 sec (120 sec goal)	Meet requirement	Test
15	3.2.1.2.7	Min Data Frequency 1/orbit	Neet requirement	Analysis

* w/o contingency

CDA, 3

HSI Requirements Summary
(from SS31-002, cont.)

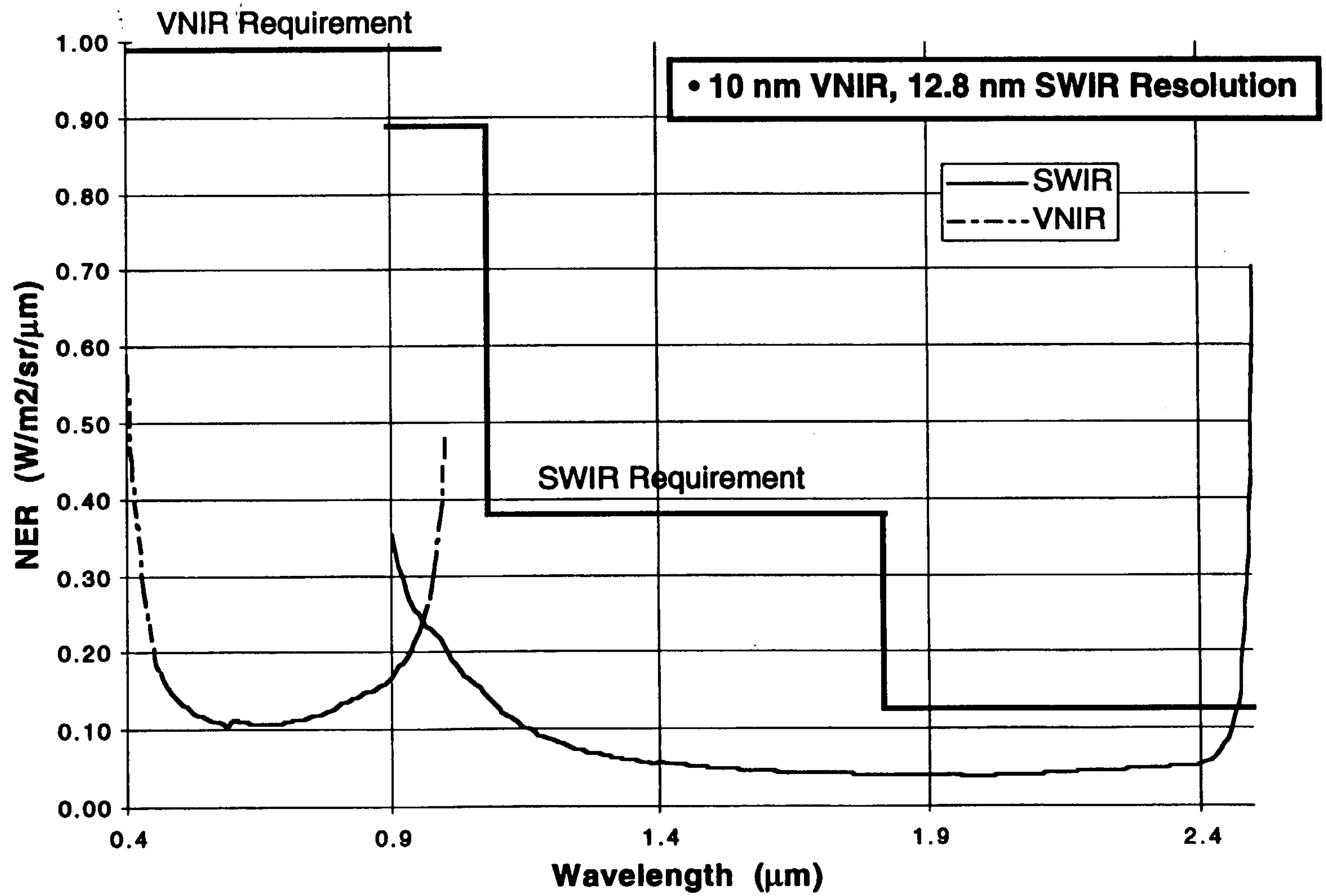
SSTI

TRW

No.	Para.	Requirement	Capability	Verification Method
16	3.2.1.2.8	Time Tag Error <2msec	1.5 msec	Analysis
17	3.2.1.2.3	Cross-track Spectral Error ≤1.0 nm (VNIR), ≤1.3 nm (SWIR)	1.0 nm (VNIR), 1.3 nm (SWIR)	Test
18	3.2.1.1.1	Number of Channels: 384 HS, 1 Pan	Same	Inspection
19	3.2.1.1.2	Spectral Bandwidth ≤10 nm	5.00+/-.16 nm (VNIR), 6.38+/-.13 nm (SWIR)	Test
20	3.2.1.1.3	Spectral Range 0.40 to 2.50 μm	Meets Requirement	Test
21	3.2.1.1.4	Spectral Accuracy ≤+/-1 nm	Meet Requirement	Analysis &Test
22	3.2.1.1.5	Spatial Co-Registration <+/-18% of IFOV within each spectrometer	Meet Requirement	Test
23	3.2.1.1.6	Spectral Band Purity ≤22% adjacent pixel, ≤5% 2 pixels away, ≤1.5% >2 pixels away	Meet Requirement	Test
24	3.2.1.3.1	Absolute Radiometric Accuracy ≤6% (1 sigma) (HS), ≤15% (1 sigma) (pan)	<4.2% (HS), <12% (pan)	Analysis & Test
25	3.2.1.3.2	Pixel to Pixel Relative Precision ≤2% (1 sigma) (HS), ≤4% (1 sigma) (pan)	<1% (HS), <2% (pan)	Analysis & Test
26	3.2.1.3.3	On-Orbit Radiometric Drift <5% (HS), <15% (pan)	<2% (HS), <3% (pan)	Analysis & Test
27	3.2.1.3.4	Noise Equivalent Radiance per Chart	See Chart	Test
28	3.2.1.3.5	Quantization 12-bit (HS), 8-bit (Pan)	Meet Requirement	Inspection
29	3.2.1.3.6	Saturation level >60% diffuse reflectance of solar irradiance @ top of atmosphere	>85% (SWIR, Max Integration Time), >100% (VNIR & Pan)	Test

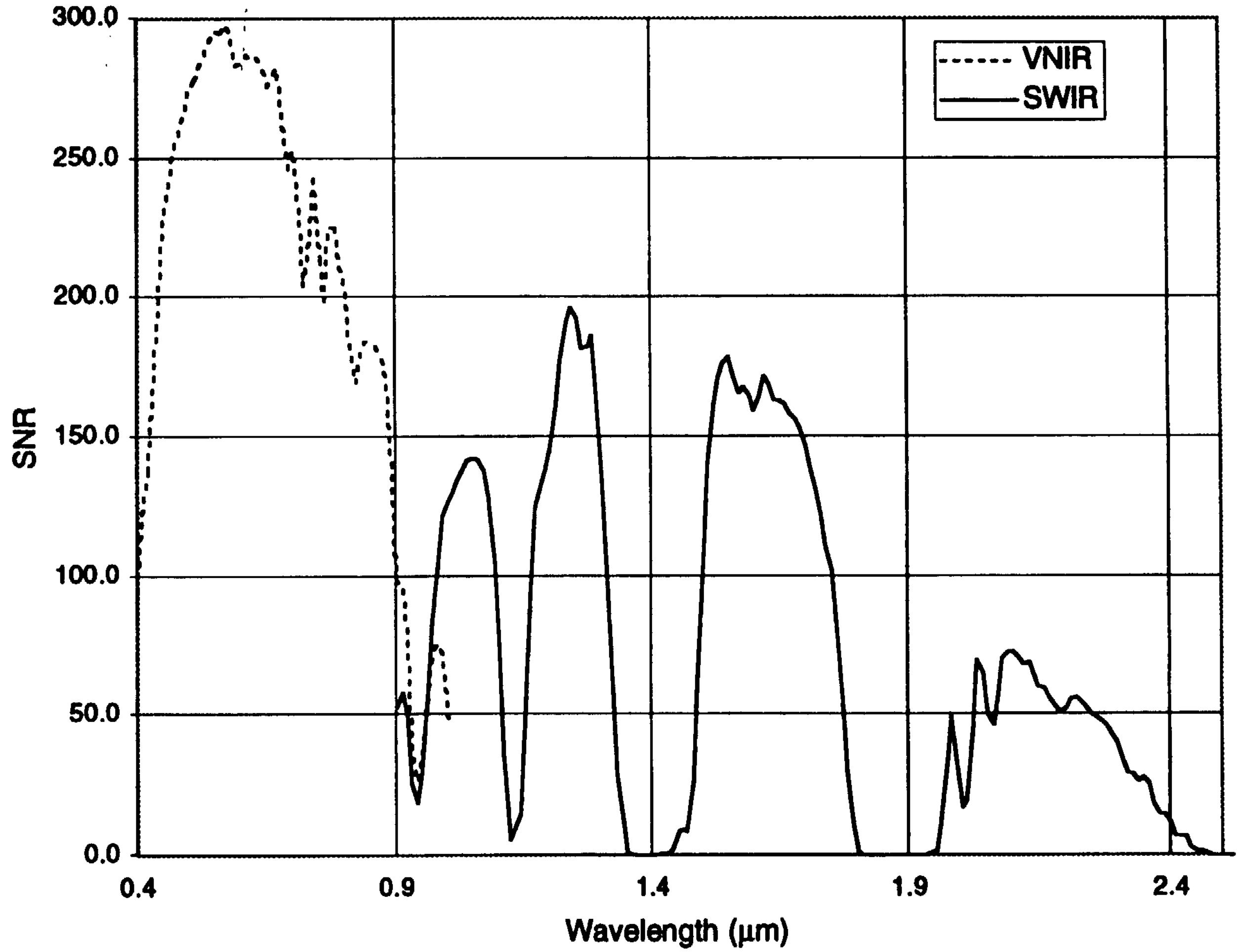
CDA, 4

HSI Noise Equivalent Radiance



CDA, 5

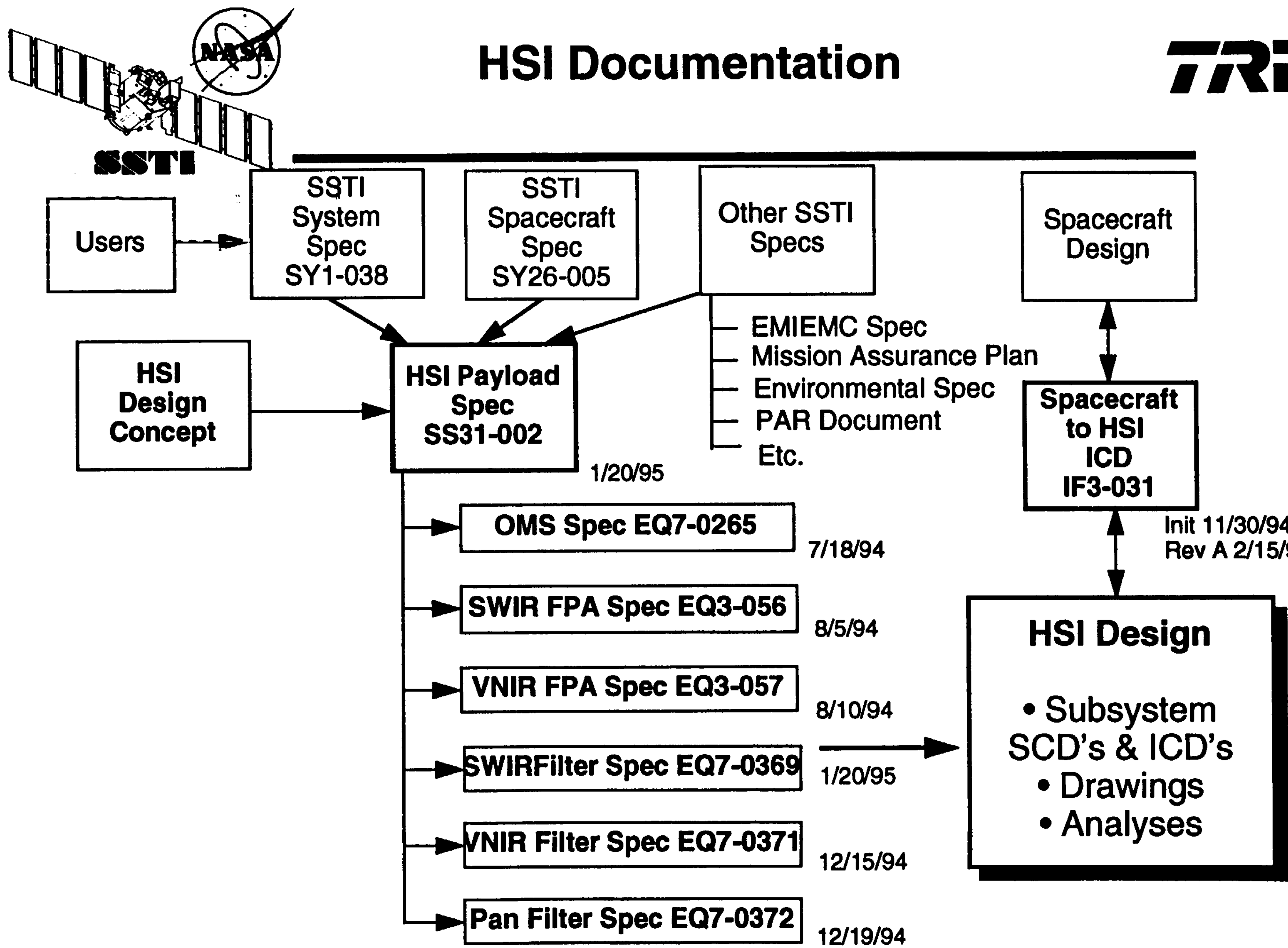
HSI Signal to Noise Ratio



- 30% Albedo, 45° N. Lat Spring Scene, 60° Solar Zenith, Nadir View
- Bandwidth 10 nm VNIR, 12.8 nm SWIR (aggregated by 2)

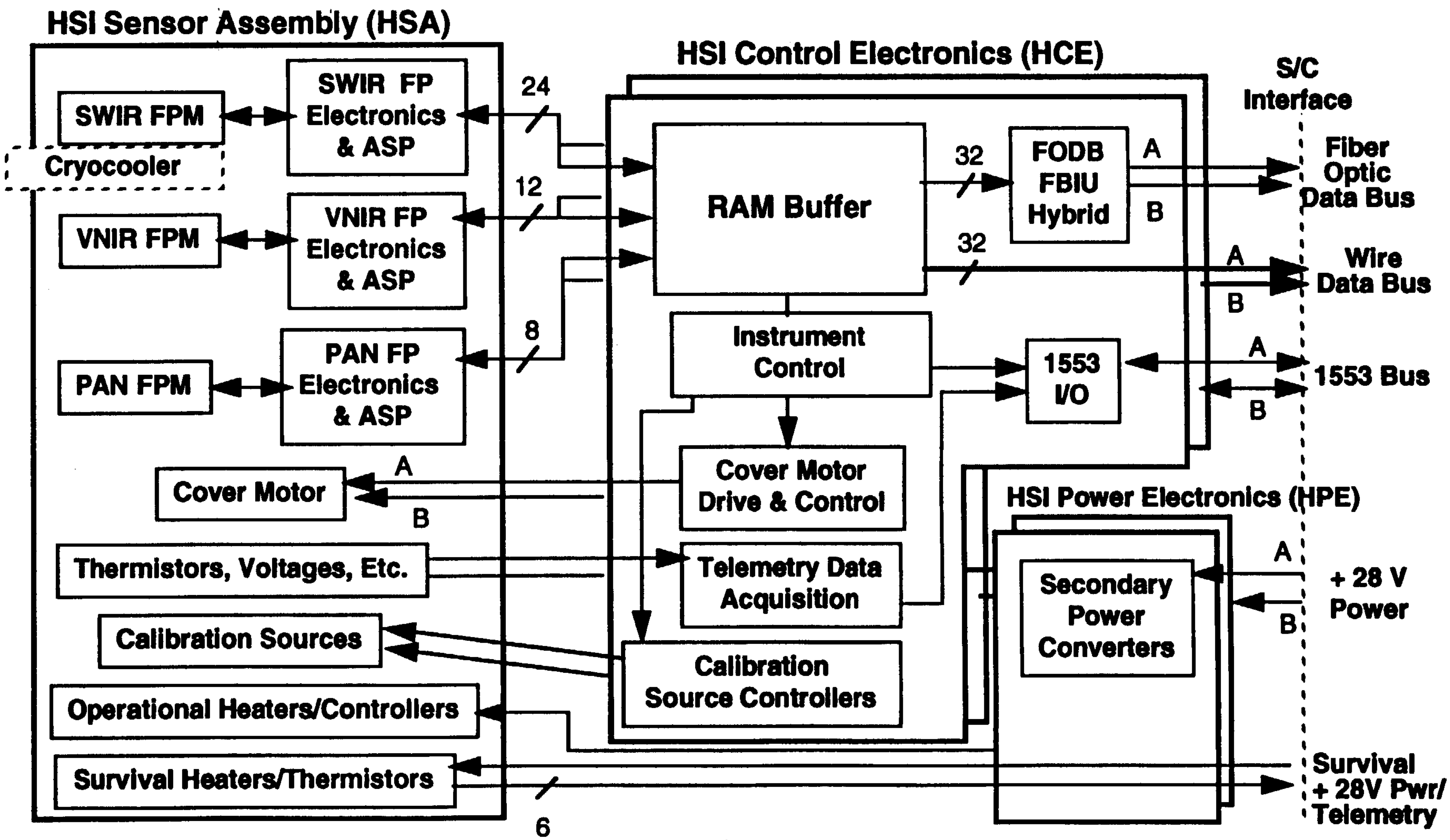
CDA, 6

HSI Documentation



CDA, 7

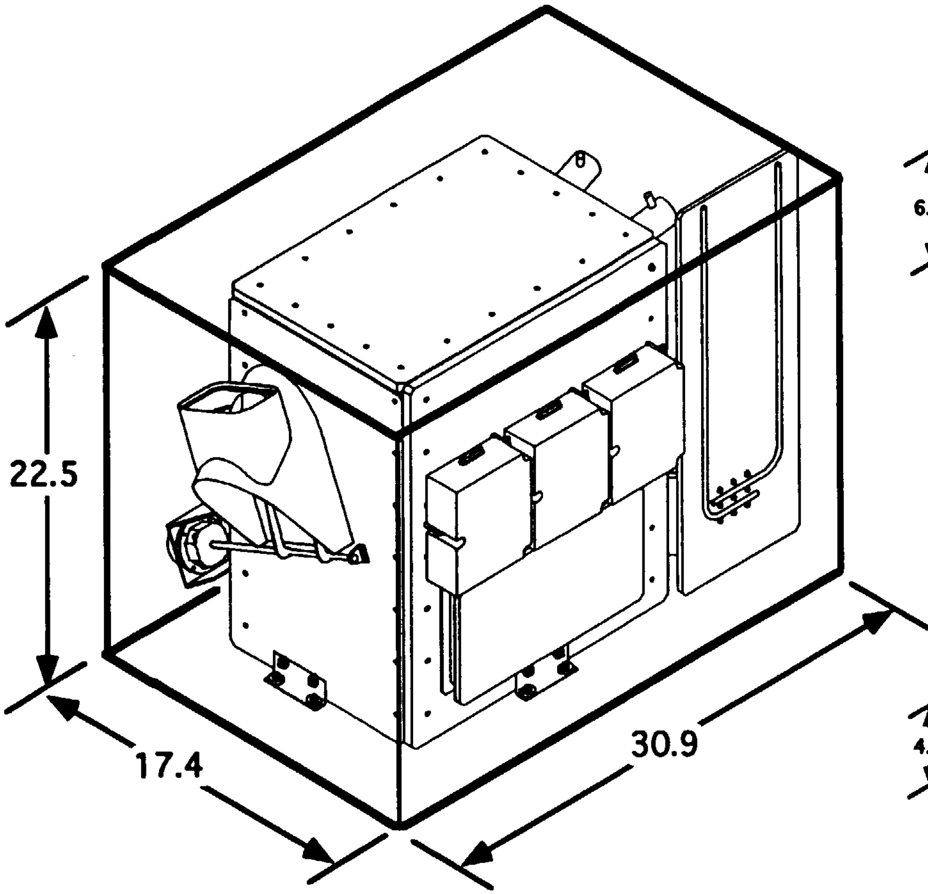
HSI Architecture



CDA, 8

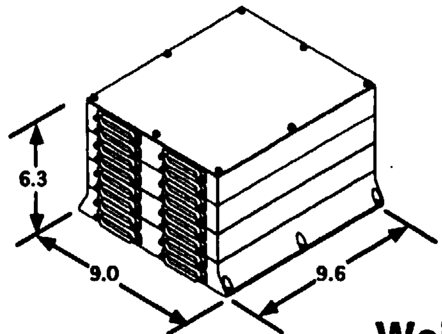
HSI Configuration Summary
(Harnesses provided by Spacecraft)

HSI Sensor Assembly (HSA)



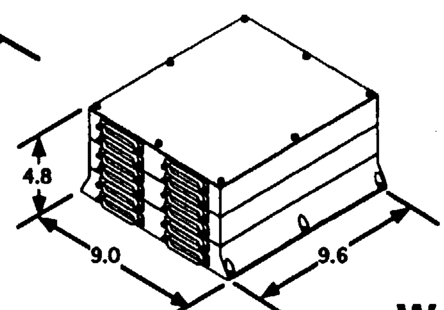
Weight: 23 Kg
Power: 33.1 W, Orbit Avg

HSI Control Electronics (HCE)



Weight: 4.3 Kg
Power: 12.9 W, Orbit Avg

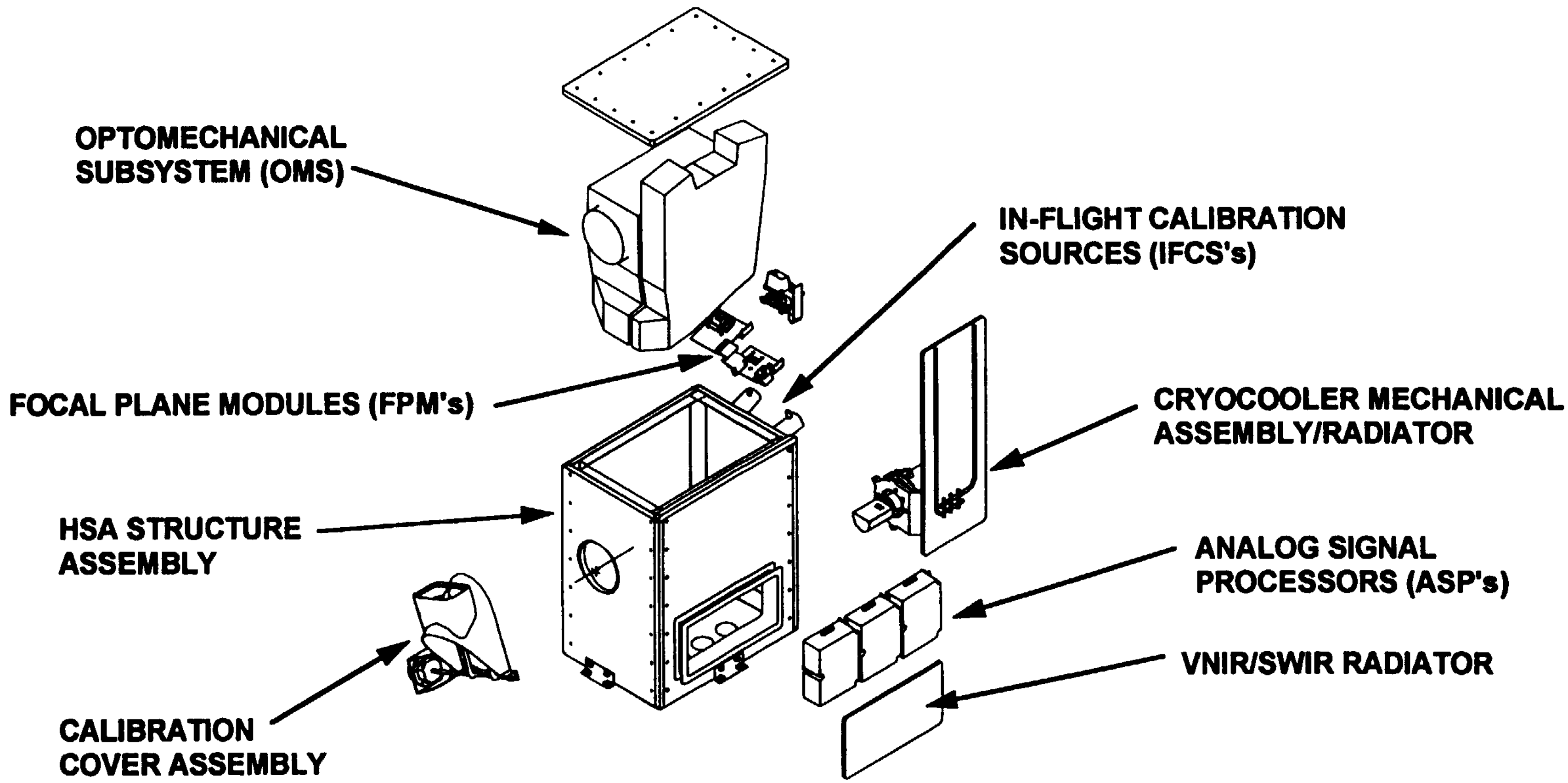
HSI Power Electronics (HPE)



Weight: 3.5 Kg
Power: 4.5 W, Orbit Avg

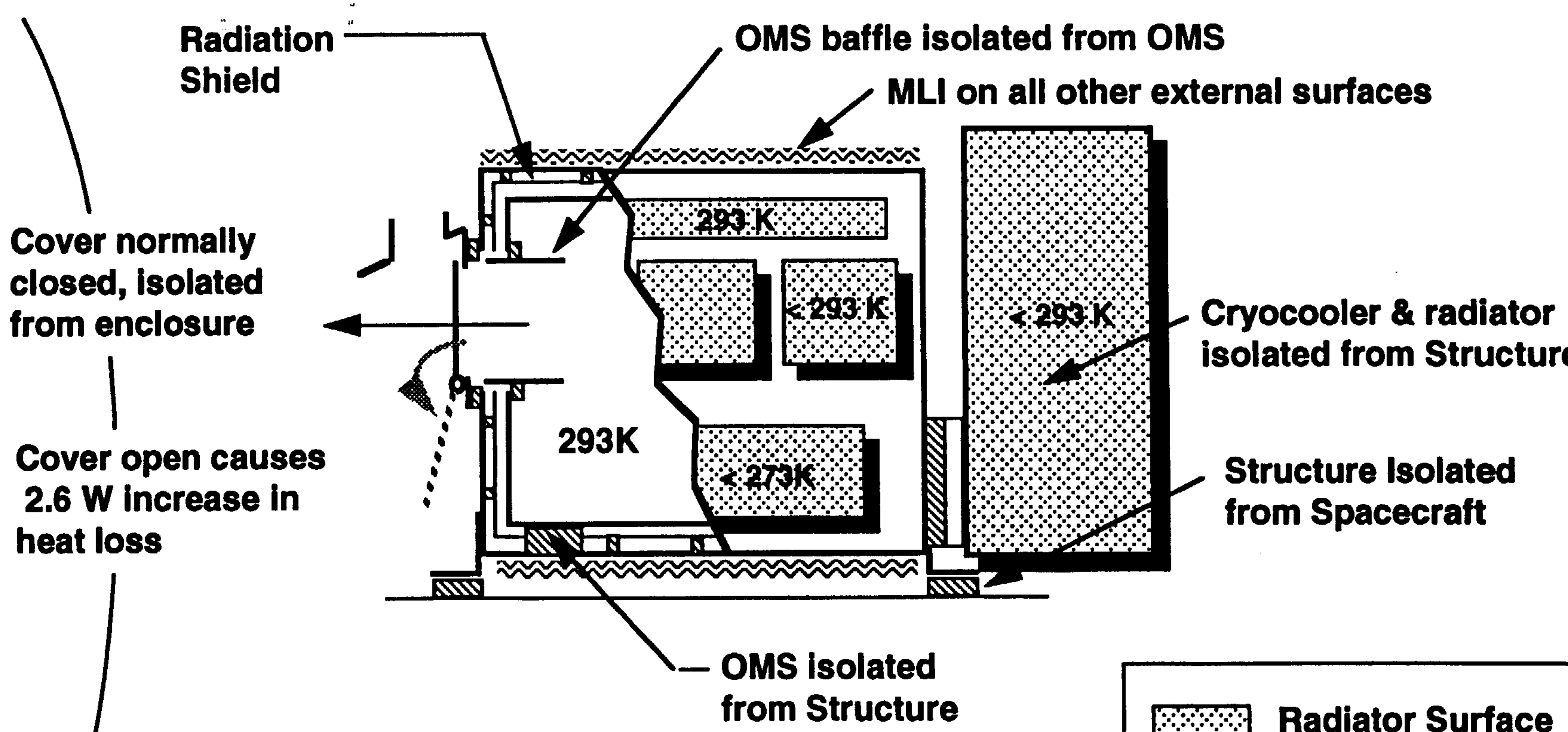
CDA, 9

HSA Exploded View

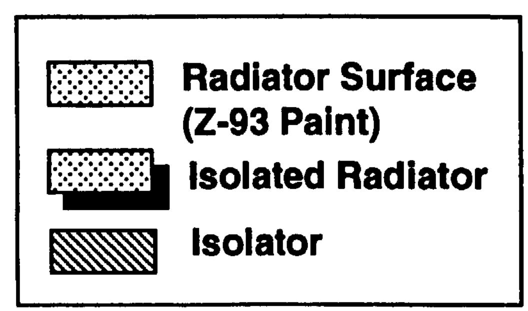


CDA, 10

HSA Thermal Design Summary

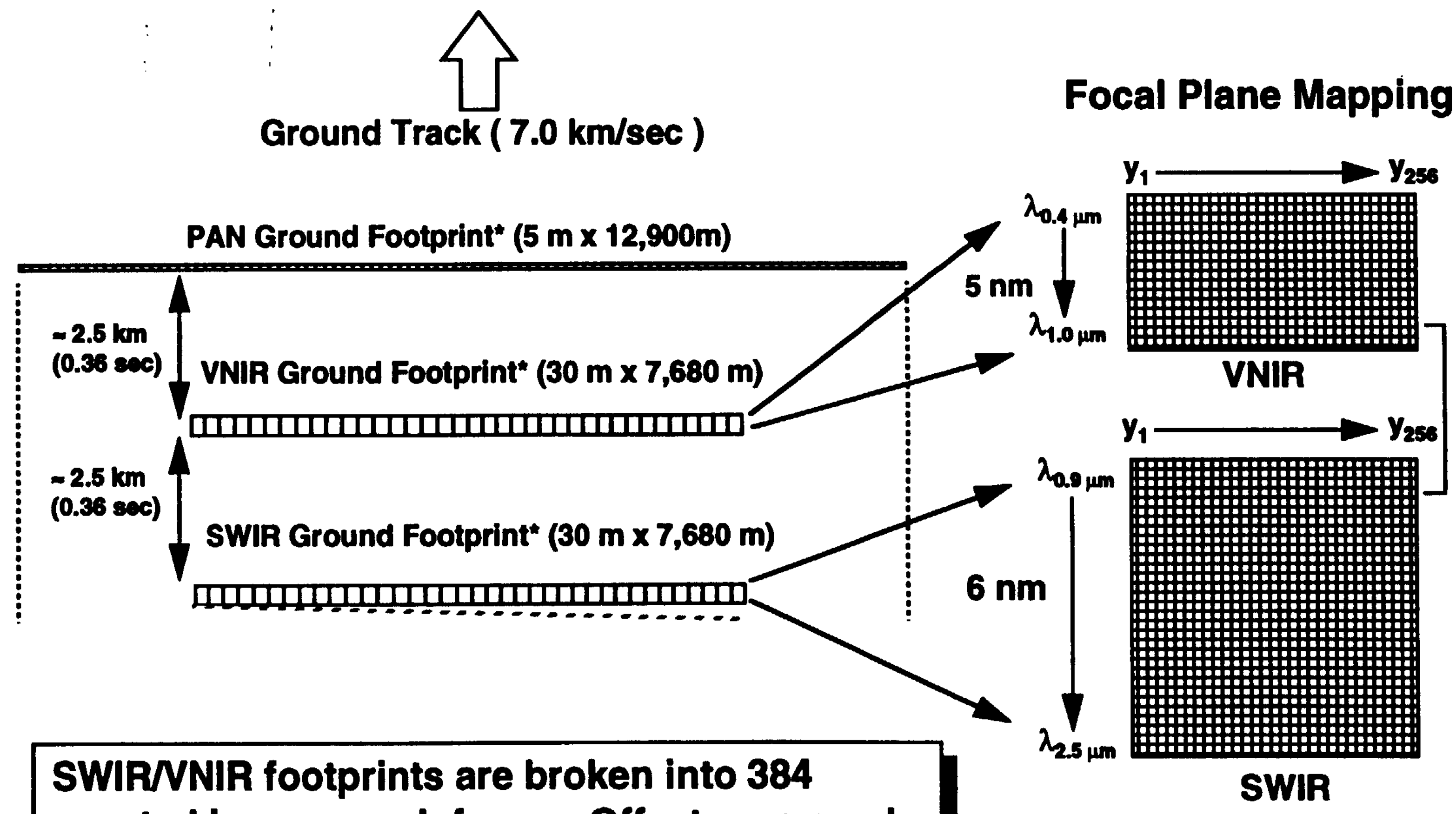


- Operational heaters maintain enclosure at constant 293K, Pan & VNIR at 273K
- Cryocooler maintains SWIR @ 115K



CDA, 11

HSI Imaging Approach



SWIR/VNIR footprints are broken into 384 spectral images each frame. Offsets removed in ground processing. 0.1 µm overlap gives constant alignment/cal check.

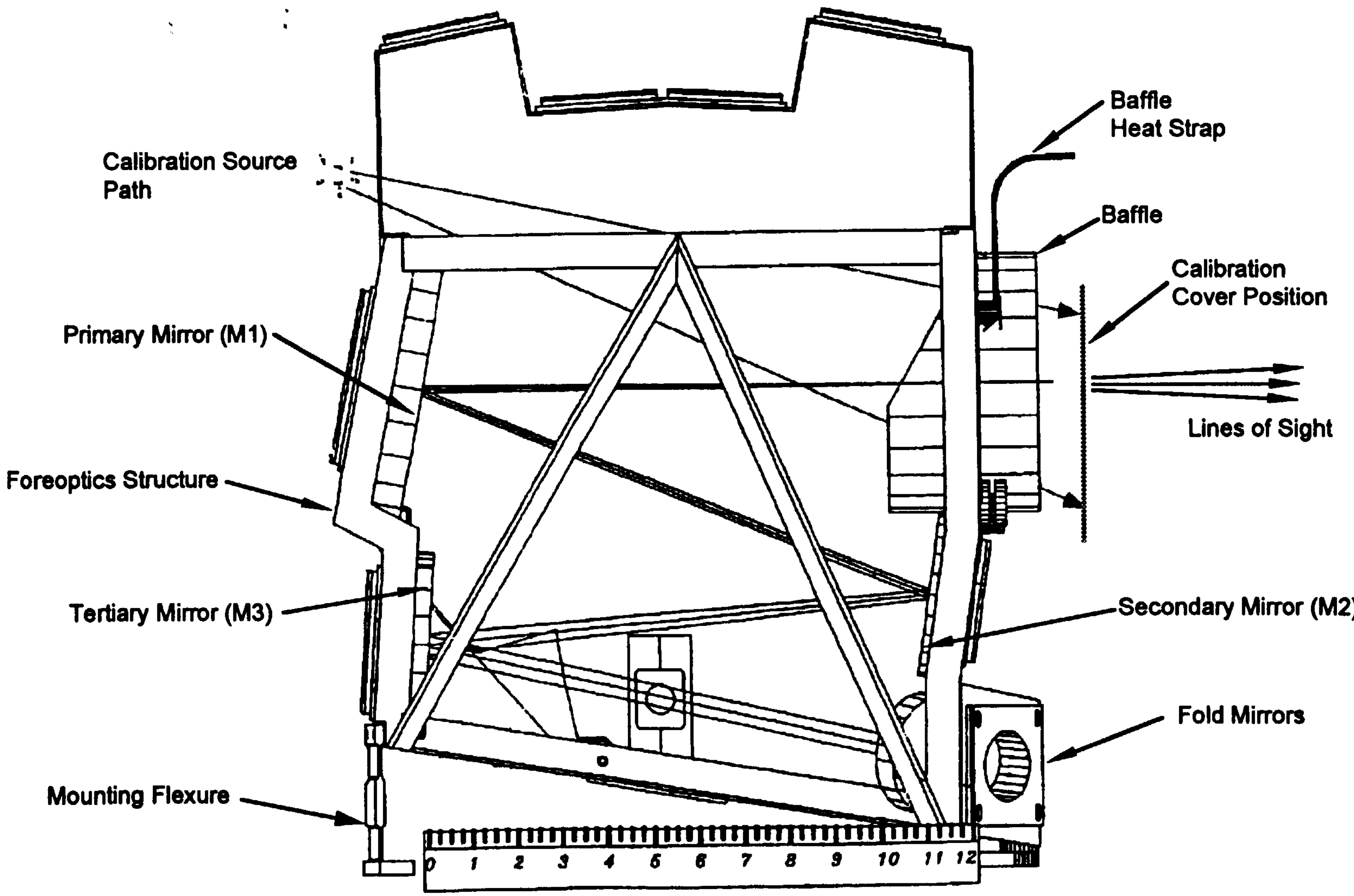
* at nadir

CDA, 12

SSTI

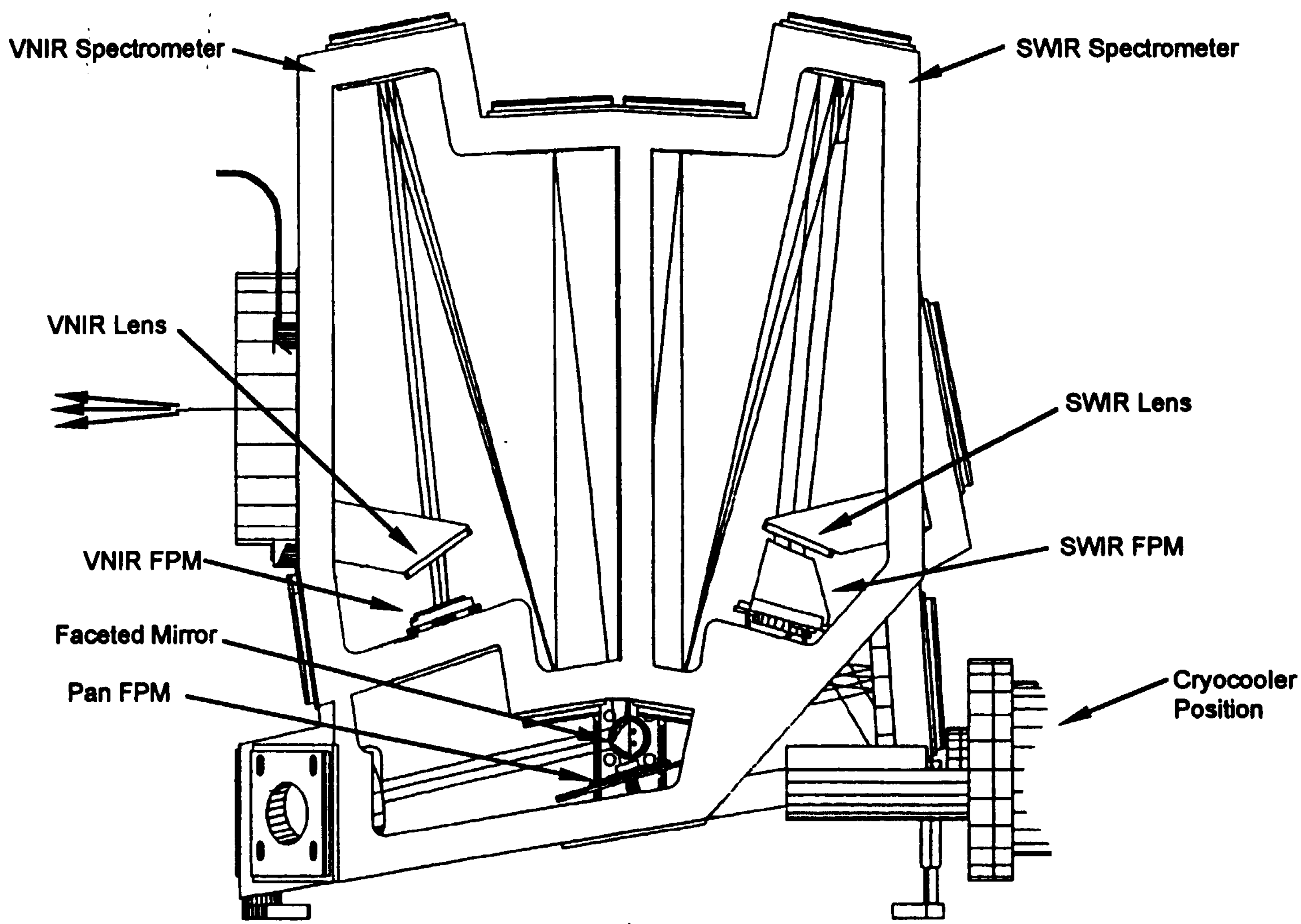
OMS Foreoptics Design
(Shear panels removed)

TRW



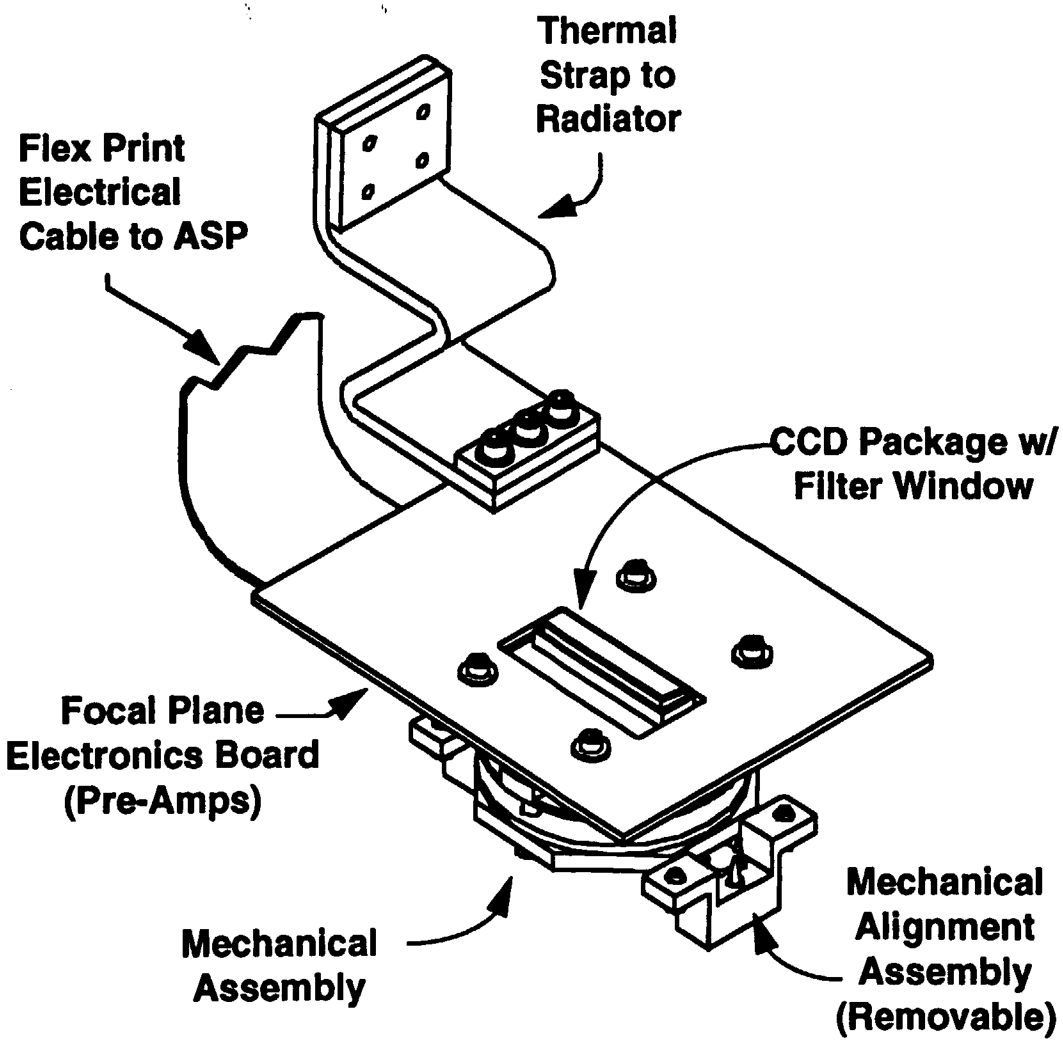
CDA, 13

OMS Spectrometer Design
(Shear panels removed)



CDA, 14

PAN Focal Plane Module

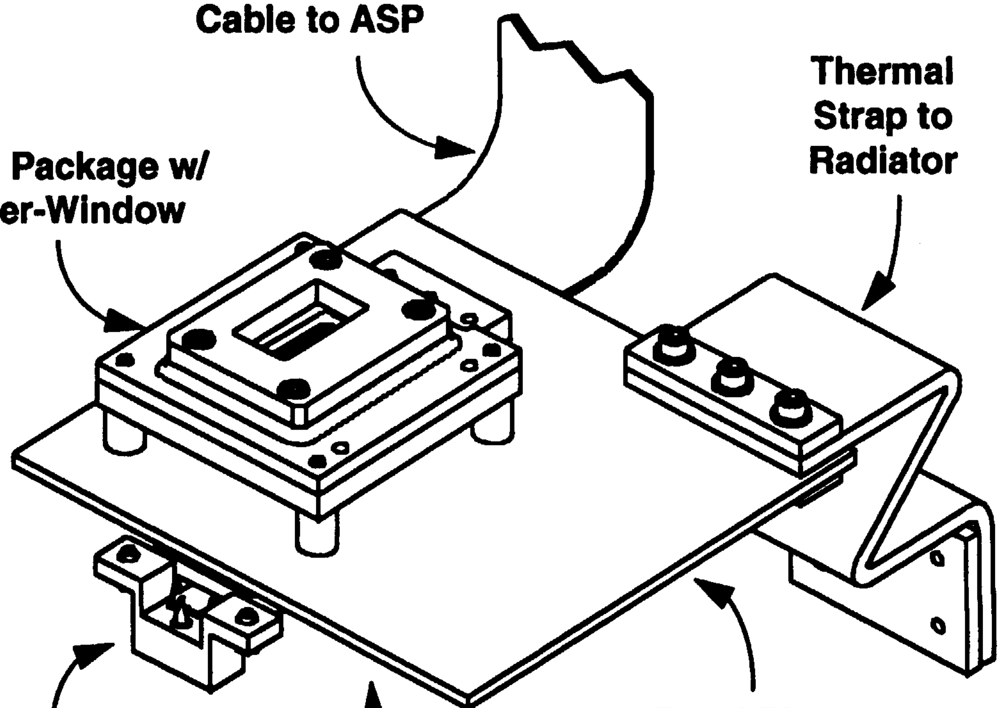


PAN FPM Summary

- Linear CCD with 2592 pixels
- 10x10 micron pixels
- 273 Kelvin Operating Temperature
- 1440 Hertz Line Rate
- 2 MHz Pixel Rate Per Port
- Pre-Amps Adjacent To CCD
- Thermal Isolation From Structure
- Thermal Strap To Passive Radiator
- Pigtailed Flex-Print Cable
- Alignment Adjustment Capability

CDA, 15

VNIR Focal Plane Module

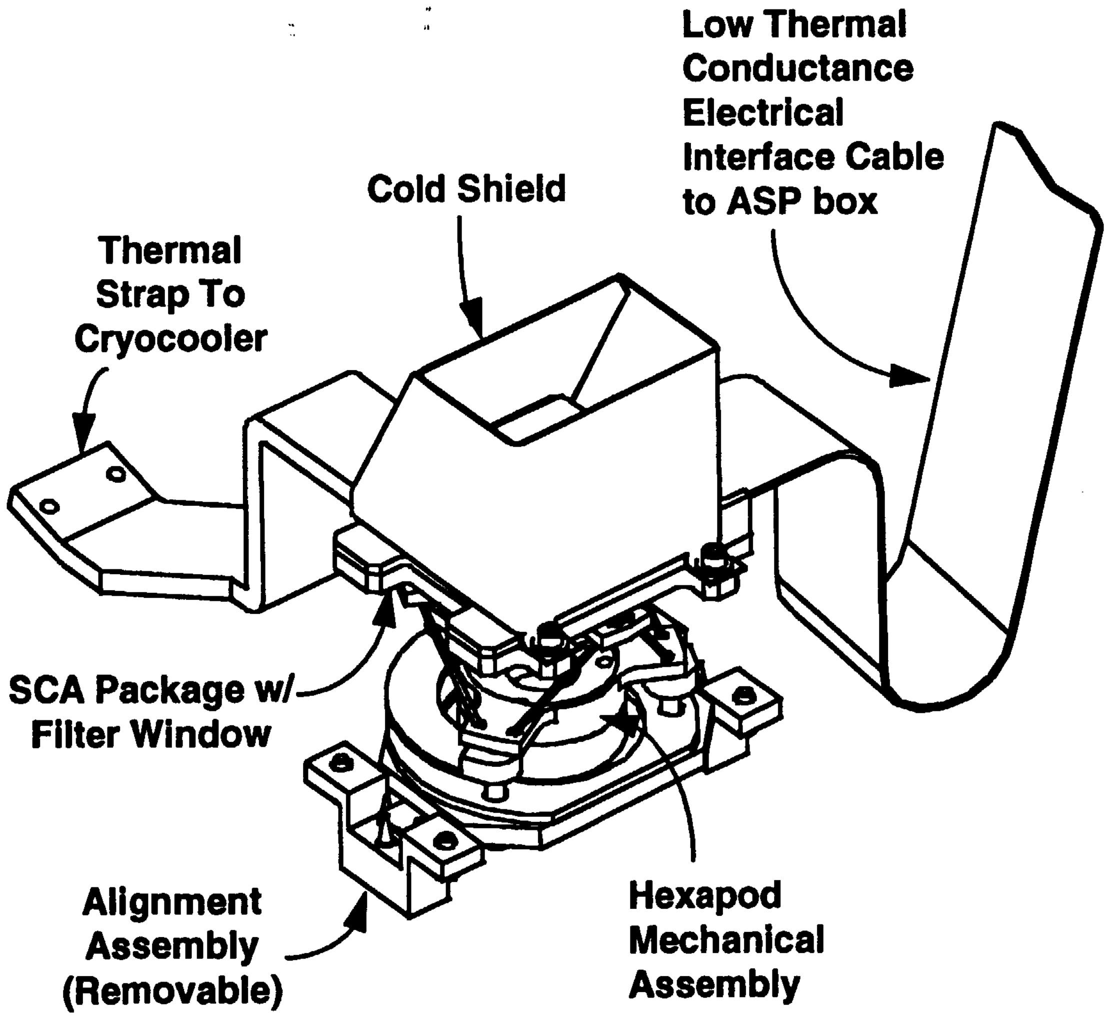


<u>VNIR FPM Summary</u>

- Area CCD Array, 256x128 Pixels
- 60x60 micron pixels
- 273 K Operating Temperature
- 240 Hertz Frame Rate
- 2 MHz Pixel Rate Per Port
- Pre-Amps, High Speed Drivers Adjacent To CCD
- Thermal Isolation From Structure
- Thermal Strap To Passive Radiator
- Pigtailed Flex-Print Cable
- Alignment Adjustment Capability

CDA, 16

SWIR Focal Plane Module

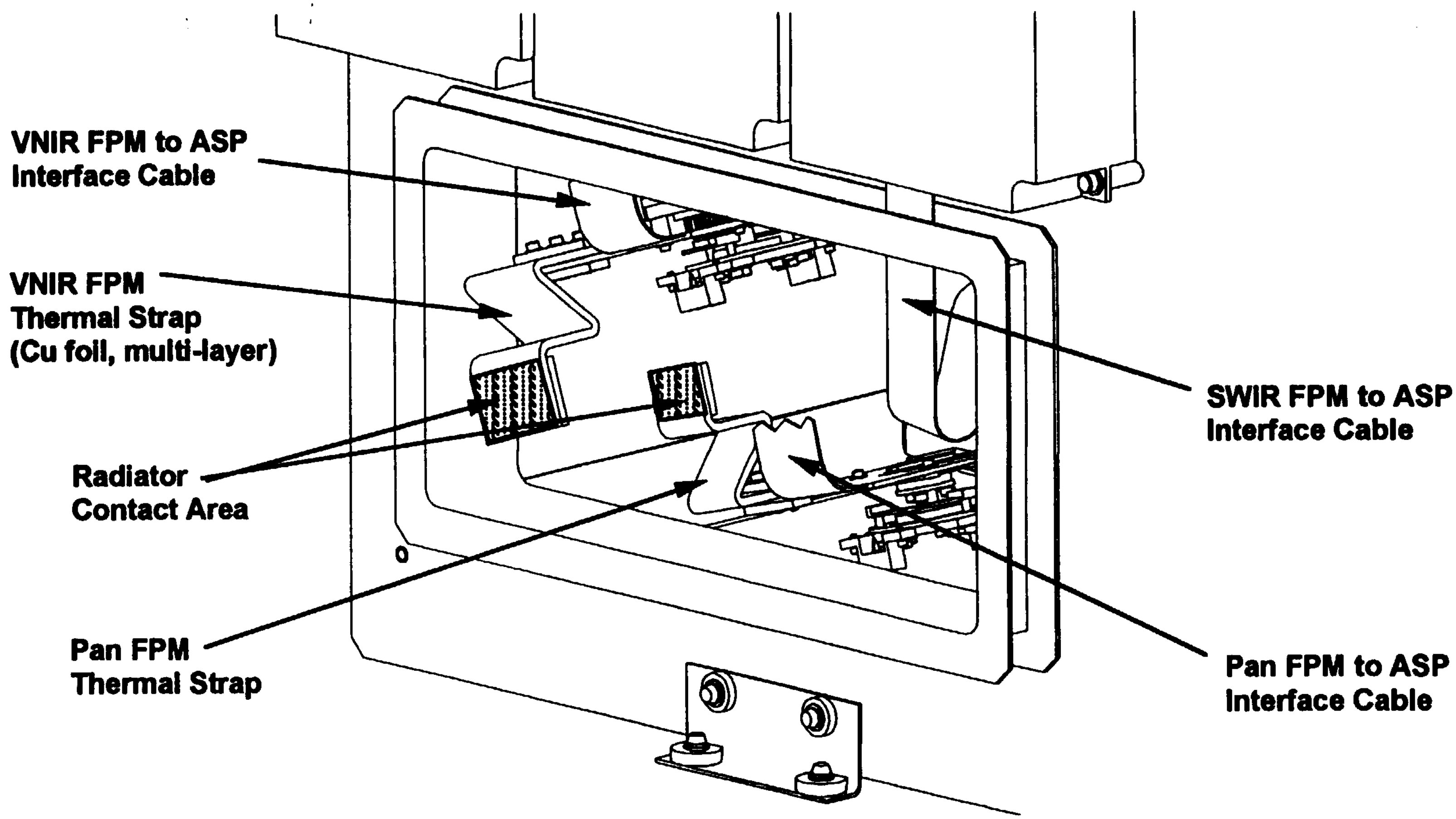


SWIR FPM Summary

- Area MCT Array, 256x256 Pixels
- 60x60 micron pixels
- 115 Kelvin Operating Temperature
- 240 Hertz Frame Rate
- 4 MHz Pixel Rate Per Port
- On Chip Pre-Amps
- Conductive & Radiative Thermal Isolation From Structure
- Thermal Strap To Cryocooler
- Pigtailed Electrical Cable To ASP
- Alignment Adjustment Capability

CDA, 17

Focal Plane Modules Installed
(Radiator and shear panels removed)



CDA, 18

SSTI

HSI Commands

Command	Type	Origin	Number of Bits
1. Sel. Primary/Redundant	Discr.	PEA	(N/A)
2. Standby Mode On Pri	Bilev.	PEA	(N/A)
3. Standby Mode On Red	Bilev.	PEA	(N/A)
4. Imaging ModeOn	Digit.	S/C OBC	1
5. Reset (Initialzation)	Digit.	G	1
6. Science Data Start	Digit.	G	1
7. Science Data Stop	Digit.	G	1
8. Internal Cal Off	Digit.	G	(TBD)
9. Internal Cal Level 1	Digit.	G	(TBD)
10. Internal Cal Level 2	Digit.	G	(TBD)
11. Internal Cal Level 3	Digit.	G	(TBD)
12. Red. Internal Cal Level 1	Digit.	G	(TBD)
13. Red. Internal Cal Level 2	Digit.	G	(TBD)
14. Cover to Solar Cal	Digit.	S/C OBC	12 ea. for
15. Cover to Open	Digit.	S/C OBC	Cover
16. Cover to Close	Digit.	S/C OBC	Position
17. Red. Cover Cal	Digit.	S/C OBC	12 ea. for
18. Red. Cover Open	Digit.	S/C OBC	Cover
19. Red. Cover Close	Digit.	S/C OBC	Position
20. Select Bands	Digit.	G	385 (TBR)
21. Primary Heaters	Digit.	G	1
22. Set SWIR Int. Time	Digit.	G	8
23. Set Pan Gain	Digit.	G	4
24. Set VNIR Offset	Digit.	G	8
25. Set SWIR Offset	Digit.	G	8
26. Set Pan Offset	Digit.	G	8
27. Update Universal Time	Digit.	S/C OBC	41 (TBR)
28.Channel Delay On/Off	Digit.	S/C OBC	1
29. Power Off Precursor	Digit.	S/C OBC	(TBD)
30 to 32. (TBD)	Digit.	(TBD)	8 ea(TBR)

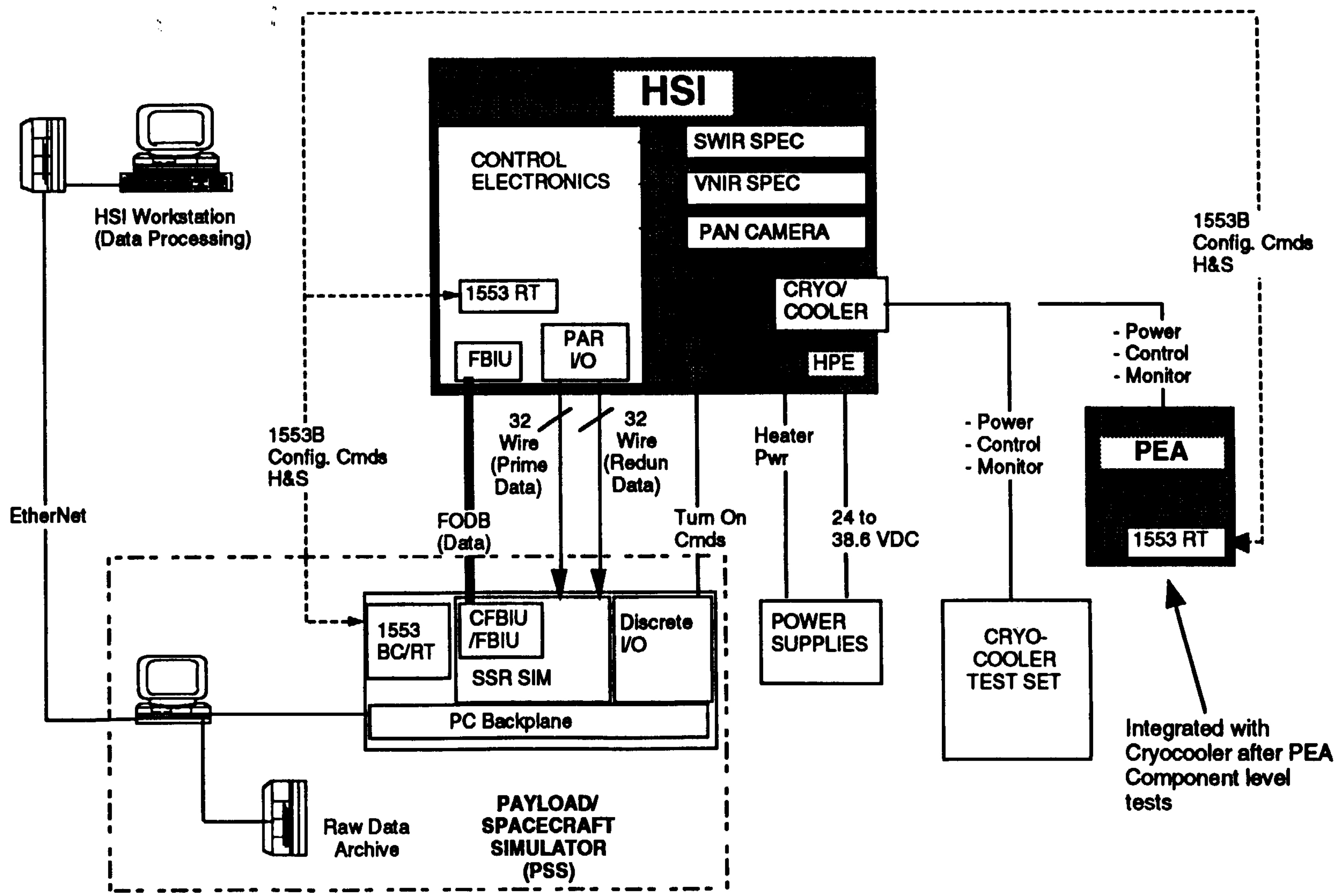
CDA, 19

HSI Integration and Test Plan

- Subsystem performance verified prior to integration
  - most include environmental testing
- Instrument integration and thermal vac will occur in Bldg. M3
  - Class 100 tunnel will be used for final assembly
- TRWIS III provides pathfinder for electrical integration and optical testing
- Optical testing/alignment will use modified Multispectral Test Bed and small vacuum chamber
- Instrument will be bagged for vibe testing and EMI/EMC
- Thermal cycles of SWIR focal plane will be minimized
- Portions of EGSE supplied by Spacecraft I & T
  - high fidelity interface verification prior to Spacecraft Integration
- HSI delivered to Spacecraft I & T for Spacecraft Integration
  - after spacecraft thermal vac
  - cleaned and bagged prior to delivery

CDA, 20

HSI EGSE Configuration



CDA, 21

SSTI

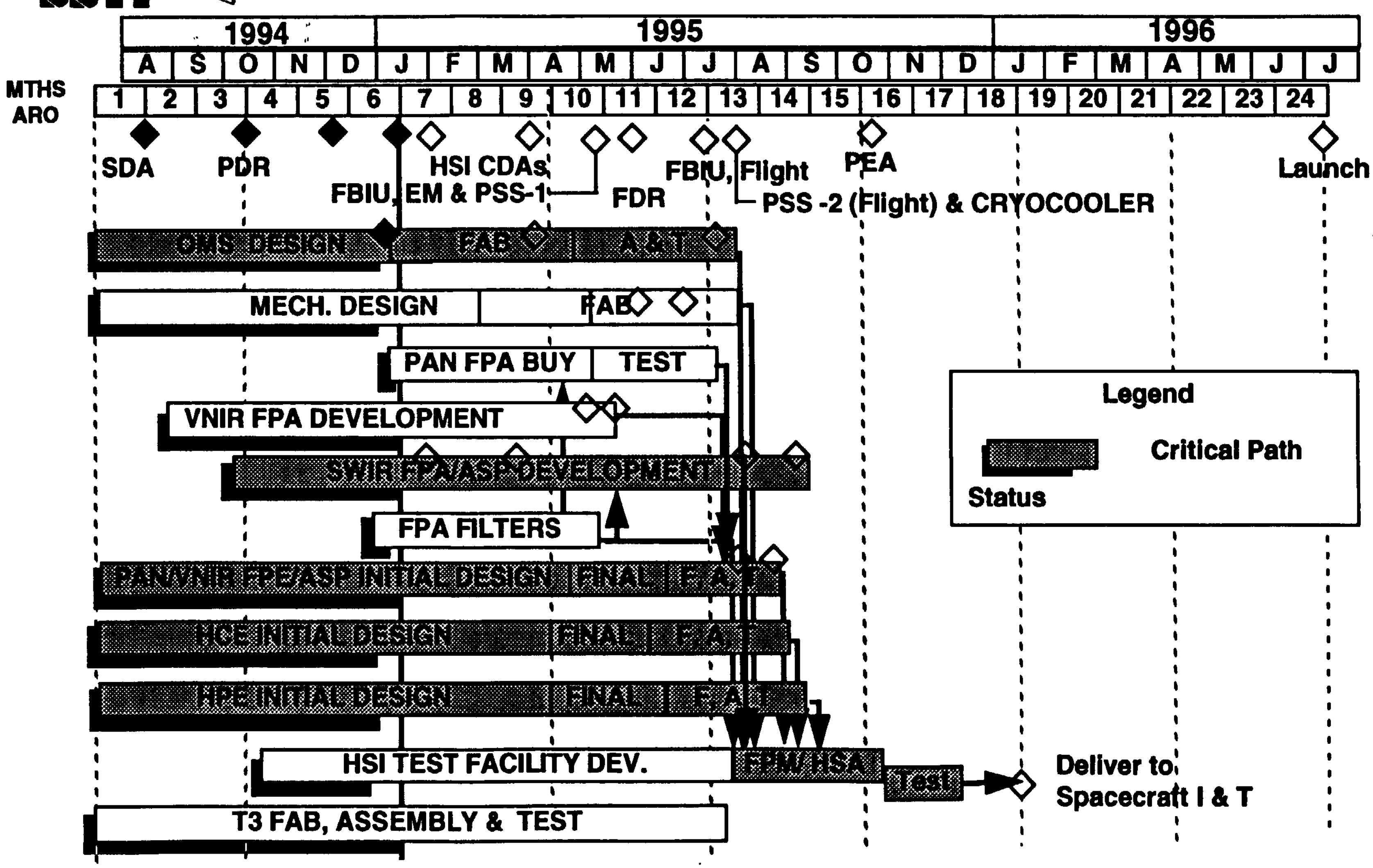
HSI Calibration & Characterization Plan

TRW

- Utilize TRW Multi-Spectral Test Bed (MSTB)
  - Stabilized source uniform across field and aperture
  - Monochromator for spectral agility
  - Source floods AΩ of calibrated detector and instrument (radiance measurement)
- Source calibrated with spectrally flat pyroelectric trap detector (uniform to .999 over .4 to 2.5 μm)
  - Developed for CERES spectral characterization
  - calibrated against Si trap, stabilized lasers & NIST sources
- Instrument housed in thermal vacuum chamber to simulate spacecraft environment
- Source scanned in narrowband mode (0.2 nm) to obtain HSI relative spectral shape
- Source scanned in wideband mode (100 nm) to obtain absolute calibration
- Source radiance adjusted to > 5 levels across dynamic range
- Multiple framed averaged to improve precision
- Source shuttered to remove zero drift
- MSTB also used to measure:
  - MTF, spatial co-registration, crosstrack spectral registration, spectral crosstalk

CDA, 22

HSI Schedule Summary



CDA, 23

HSI Status

- Instrument
  - 5 yr life design underway, schedule replan complete
  - Incremental review plan, CDA-1 on February 2 & 3
  - Instrument Spec ready for release
  - Data Interface still an issue
    - » 32 Wire protocol/drivers
    - » FODB FBIU availability
  - Filter Specs for Pan and VNIR focal planes released
    - » Filter quotes received, order placed
- Mechanical Subsystem
  - Sensor Assembly design being detailed
  - FPM adjustment mechanism demonstrated
  - Additional manpower being sought to speed up release schedule
- Optomechanical Subsystem (SSG, Inc)
  - CDR completed, working FPM interface and analysis issues
  - Grating masters being ruled
  - Drawing release underway

CDA, 24

SSTI

HSI Status

TRW

- Focal Planes
  - Panchromatic CCD FPA, Loral Fairchild Imaging Systems (LFIS)
    - » Order placed for arrays
  - VNIR CCD FPA, Loral Fairchild Imaging Systems (LFIS)
    - » Wafer fab complete, awaiting results of probe test
  - SWIR HCT FPA, Rockwell
    - » Mux CDR this month
    - » Frequent TIMs being held to finalize interface details
- Electronics Subsystem
  - 5 yr design changes finalized, schedule replanning completed
  - Current manpower problems solved
  - Parts lists being completed, long lead parts procurement underway
    - » parts problems being worked

CDA, 25

SSTI

PAYLOADS & TECHNOLOGY DEMONSTRATIONS
LEISA

D. Reuter

GENERAL OVERVIEW

- LEISA is complementary to HSI in the infrared. Image Size and Spatial Resolution are 10 times larger than HSI.

- 2-D Spectral Imager. Single Frame is 2-D Spatial, 1-D Spectral. Mapping is done in Push-Broom Mode.

- Linear Variable Etalon (LVE) Spectral Filter is Placed in Front of a NICMOS 3 array. Wavelength is a Function of Position on Array.

- Array Field-of-View (FOV): 77 km
  Pixel Field-of-View (IFOV): 300 m

- Spectral Coverage: 1.0 - 2.5 μm
  Spectral Resolving Power ($\lambda/\Delta\lambda$): 250

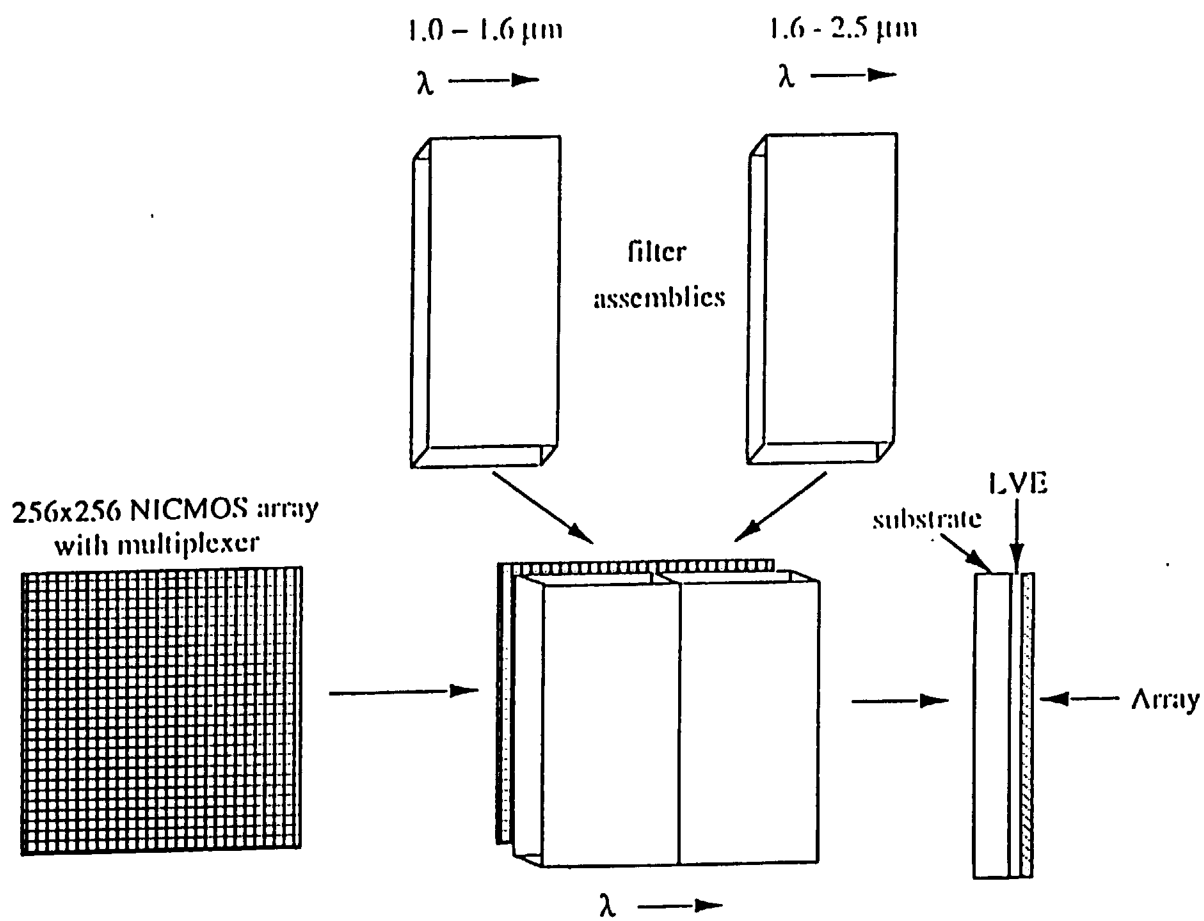
- LEISA will be pointed with an Optical Pointing Assembly and Cooled with a Pulse-Tube Cooler (both supplied by TRW).

SCIENCE GOALS

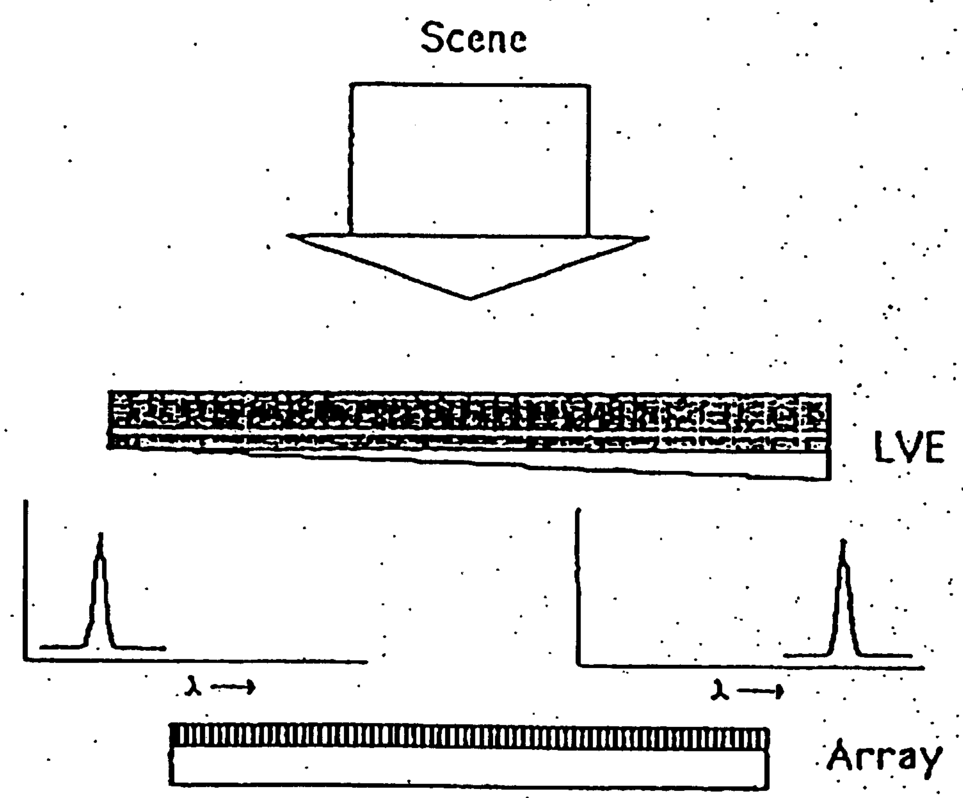
- Map Reflectance Spectra of Surface and Atmospheric Features.
- Study Earth and Environment using infrared measurements of Radiance Continuum and Diagnostic Absorption Features.
- Typical Targets:

    Geology and Minerals
    Soil and Vegetation
    Coastal and Fresh Water
    Industrial Effluent
    Volcanoes
    Forest Fires
    Oil Spills
    Aurora and Airglow
    Clouds

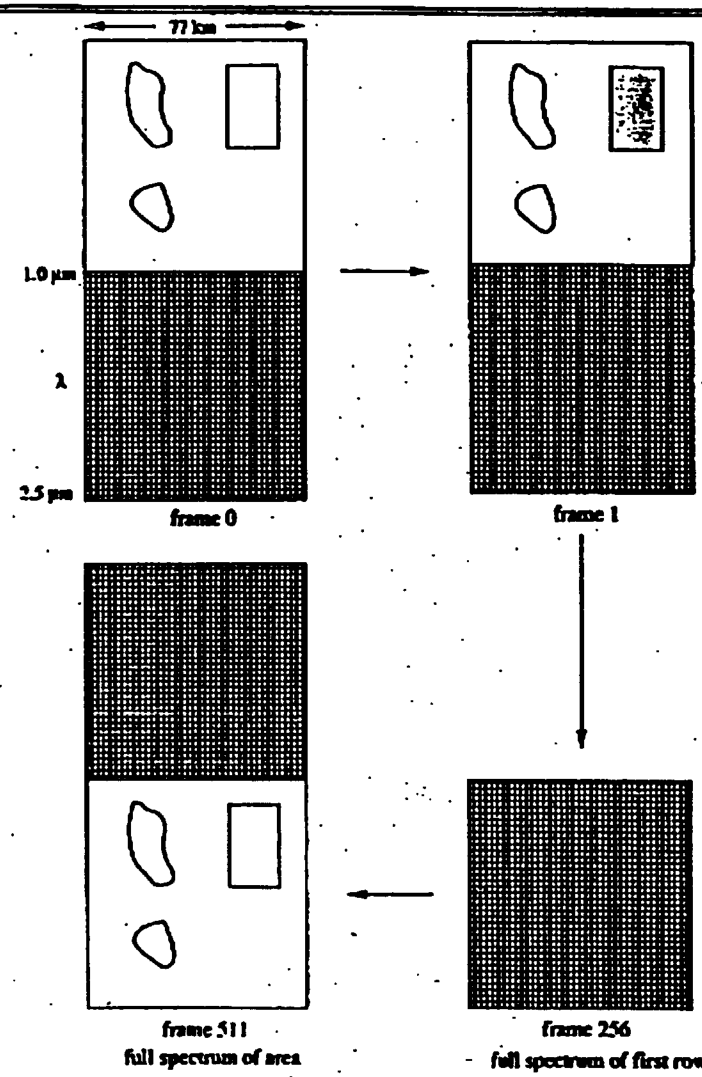
LVE AND NICMOS ARRAY CONFIGURATION



LVE OPERATION



SCAN SCHEMATIC



INSTRUMENT PARAMETERS

Type of Spectrometer: Linear variable etalon (LVE)

Spectral Coverage: 1.0 to 2.5 μm

Spectral Resolving Power ($\lambda/\Delta\lambda$): 250

Pixel FOV: 0.57 x 0.57 $mrad^2$ (300 x 300 m^2 for 523 km orbit)

Array FOV: 147 x 147 $mrad^2$ (76.8 x 76.8 km^2 for 523 km orbit)

Frame Rate: nominal 28 Hz; slower rates commandable

Dynamic Range: 4096 (12 bit A/D)

Memory Required per 77 x 77 km^2 Area: 270 Mbits (no compression)

Type of Detector: NICMOS3 256 x 256 HgCdTe array

Operating Temperature: 83±5 K (stable to ±1 K)

Power (Optics Module): 7.3 W

Mass (Optics Module): 2.5 kg

Commands: Frame Rate, Logic Reset, Data Start/Stop

GSFC/TRW SUPPLIED HARDWARE

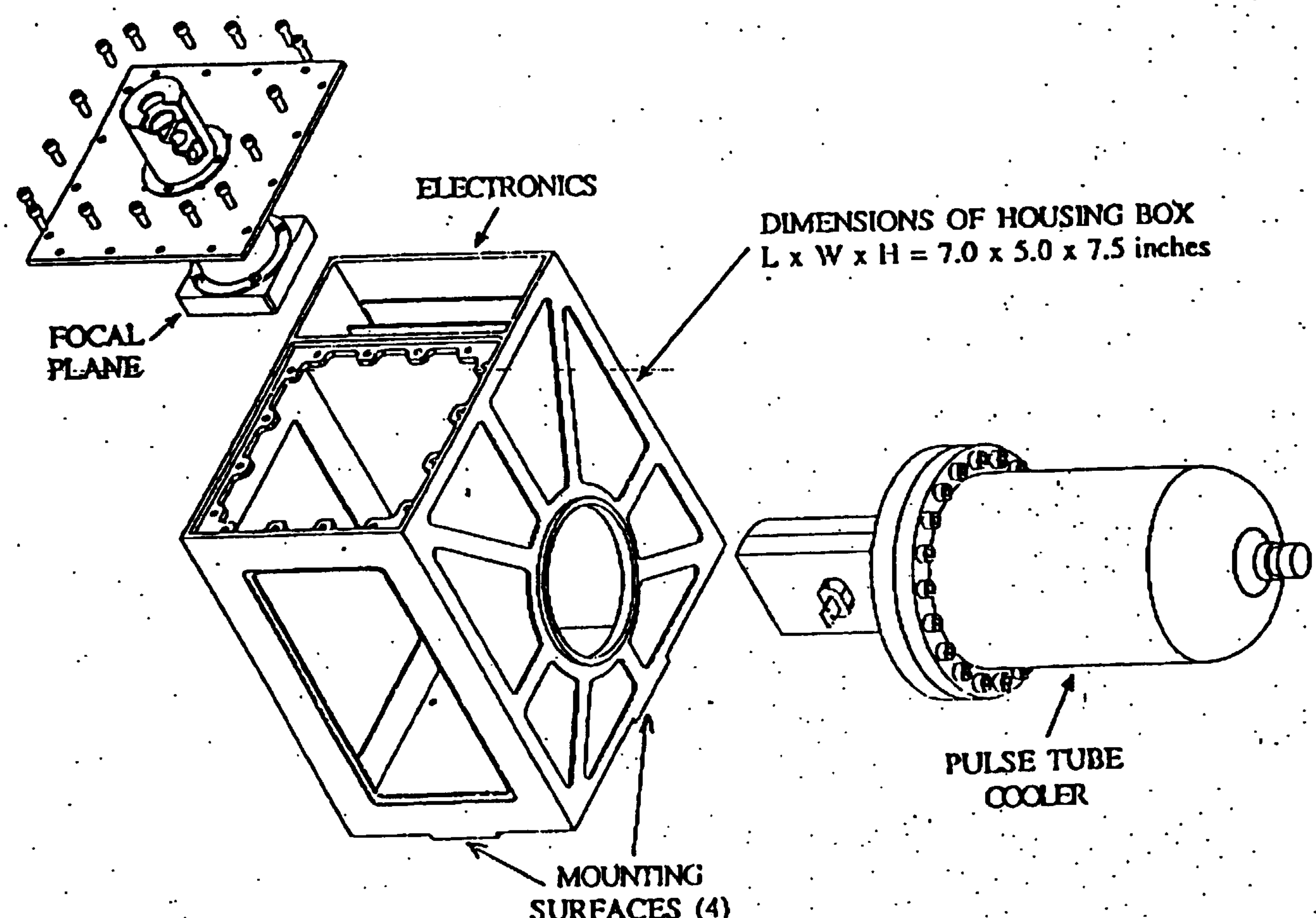
- GSFC Supplied Items:
  - LEISA Optics Module
  - GEM Board

- TRW Supplied Items:
  - Cryocooler
  - Optical Pointing Assembly
  - LASS Support Bracket
  - Cables

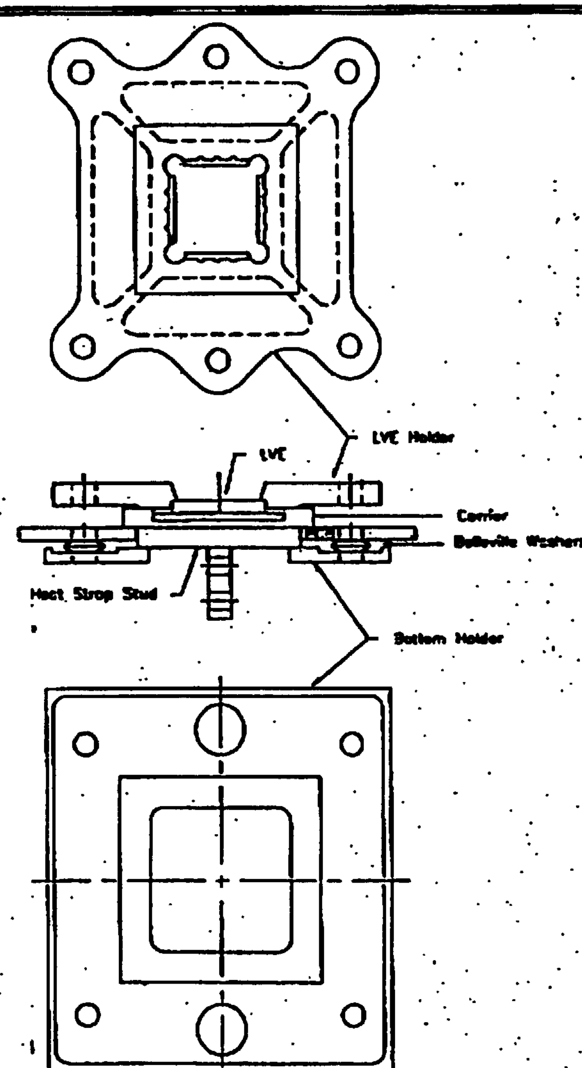
INSTRUMENT STATUS

- Mechanical Design of Optics Module 90% Complete.
- Electronics Conceptual Design 70% Complete.
  Parts Specified and Procurement Process Initiated.
  Board Layouts in Progress.
- Focal Plane Design 90% Complete.
  Parts being Fabricated.
- Data Rates and Format Specified.
- Commands Specified.
- LVE Contract in Final Award Phase
- Lens Contract Awarded.

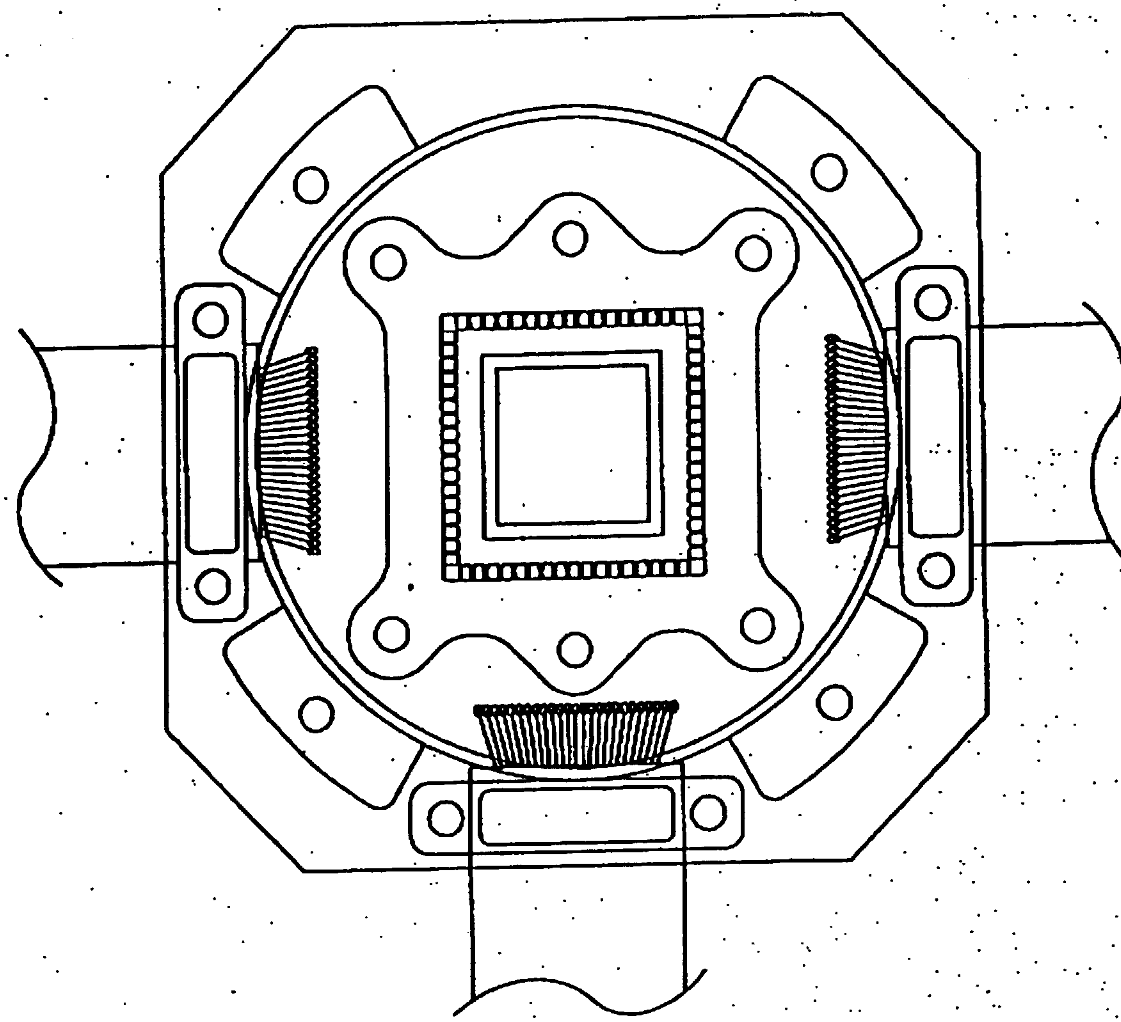
MECHANICAL CONFIGURATION



FOCAL PLANE ASSEMBLY



FOCAL PLANE
View Through LVE Holder



ELECTRONICS CONFIGURATION

- Two Boards will be mounted on the Optics Housing:

  Analog Board: Preamps, Bias, A/D's

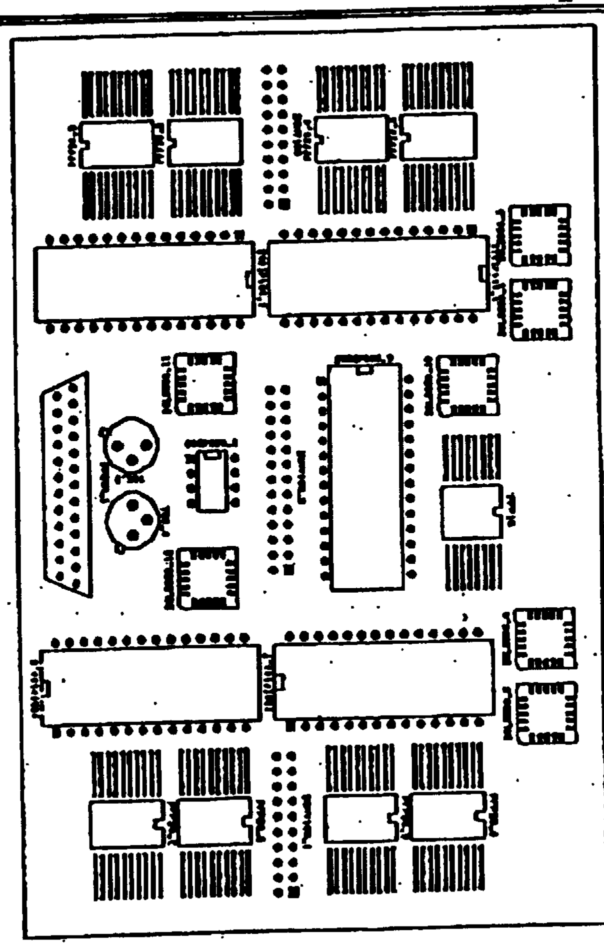
  Digital Board: FPGA, Clock, CDS, Mux

- One Board will be mounted in the GEM:

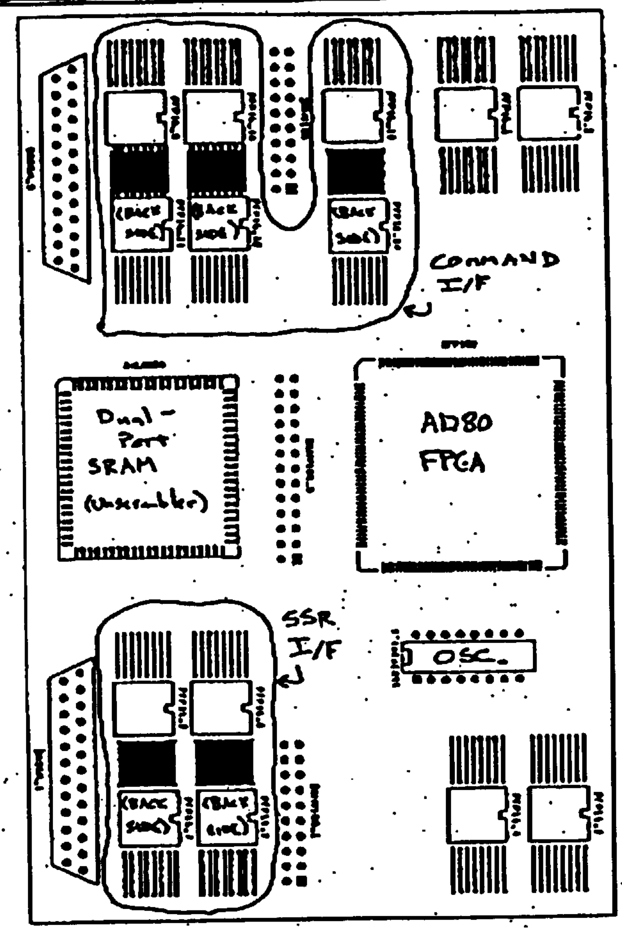
  GEM Board: Power Pass-Through from GEM LVPS
1553 Bus Interface

ELECTRONICS BOARDS

Component Layout



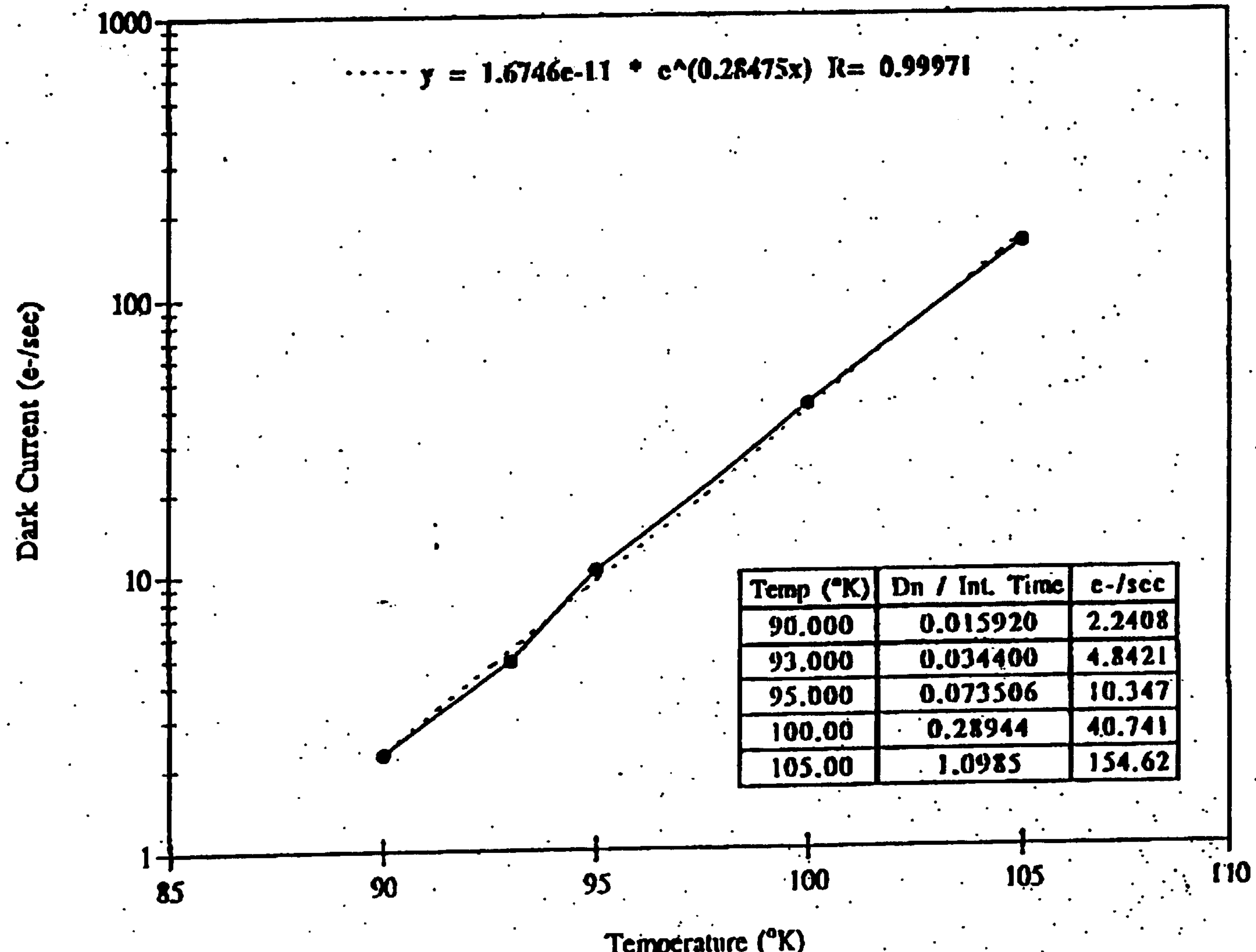
ANALOG BOARD



DIGITAL BOARD

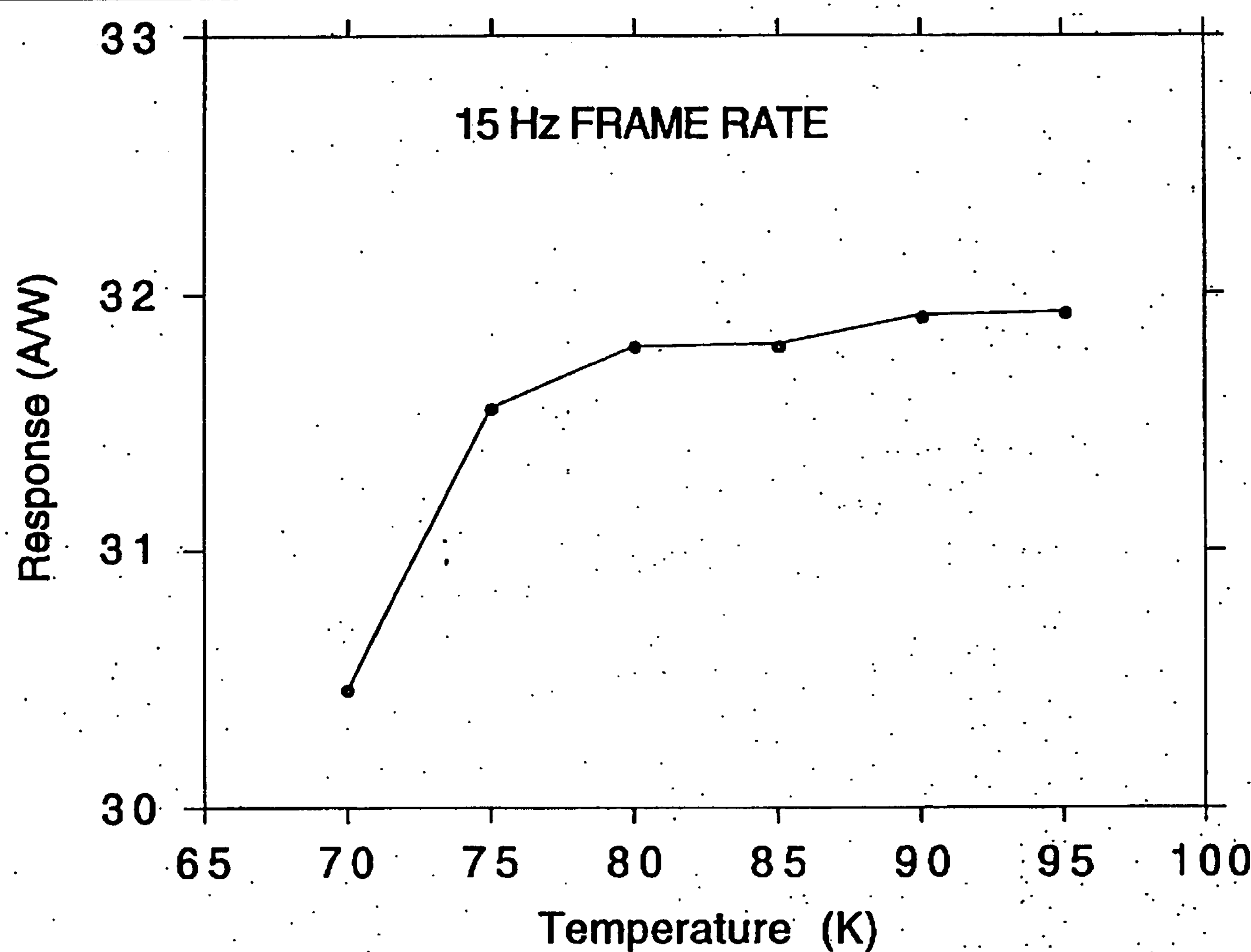
LEISA

NICMOS 3 DARK CURRENT Vs. TEMPERATURE



Temp (°K)	Dn / Int. Time	e-/sec
90.000	0.015920	2.2408
93.000	0.034400	4.8421
95.000	0.073506	10.347
100.00	0.28944	40.741
105.00	1.0985	154.62

NICMOS 3 RESPONSE Vs. TEMPERATURE



MASS AND POWER

MASS:	OpticsModule	2.5 kg
	GEM Board	TBD (0.7 kg)
POWER:	Optics Module	7.3 watts
	GEM Board	1.8
		9.1 watts

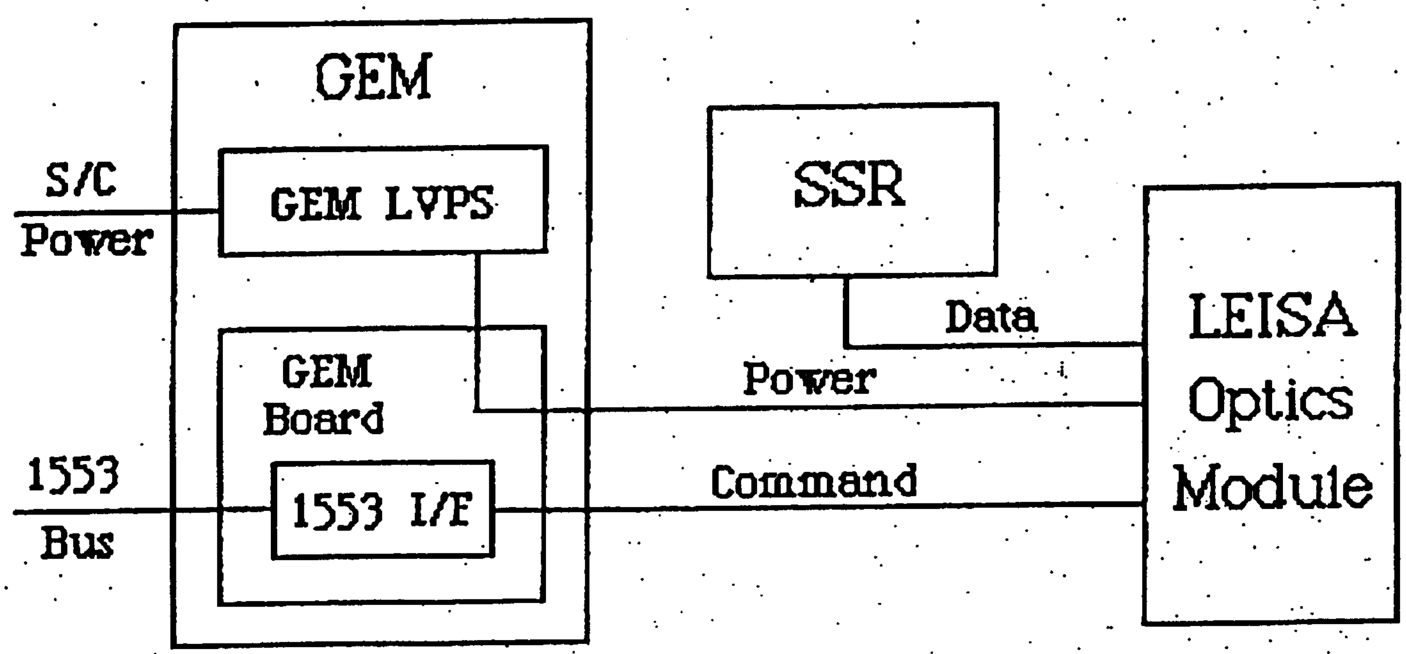
STATUS OF INTERFACES

- MECHANICAL:
  - LASS Support Bracket is Being Built by TRW.
  - Optics Module Mounting Interface has been Specified.
- THERMAL:
  - Optics Module Heat Sink Approach being Worked by TRW and GSFC.
  - Interface of LEISA to Cryocooler has been Specified.
- OPTICAL:
  - Alignment Tolerances to OPA and LASS have been Specified. Alignment Plan Tentatively Agreed upon with TRW.

STATUS OF INTERFACES (con't)

- ELECTRICAL:
  - Two Cable Interfaces:
    - Data Cable: Optics Module-SSR
    - Power/Command Cable: Optics Module-GEM
    - Cables to be supplied by TRW.
      GSFC has specified Connectors and Pinouts.
  - Data Format and Rates have been Specified by GSFC.
  - Commands and H&S have been Specified by GSFC.
  - Power to be Supplied from GEM LVPS.
    Requirements have been agreed upon with GEM.

ELECTRICAL INTERFACES



SSR DATA

- Data Will be Sent Directly to SSR on Two Redundant Sets of Six Lines (4 Data Lines, 1 Clock Line, 1 Write Enable Line). Clock Rate 7.5 Mhz.

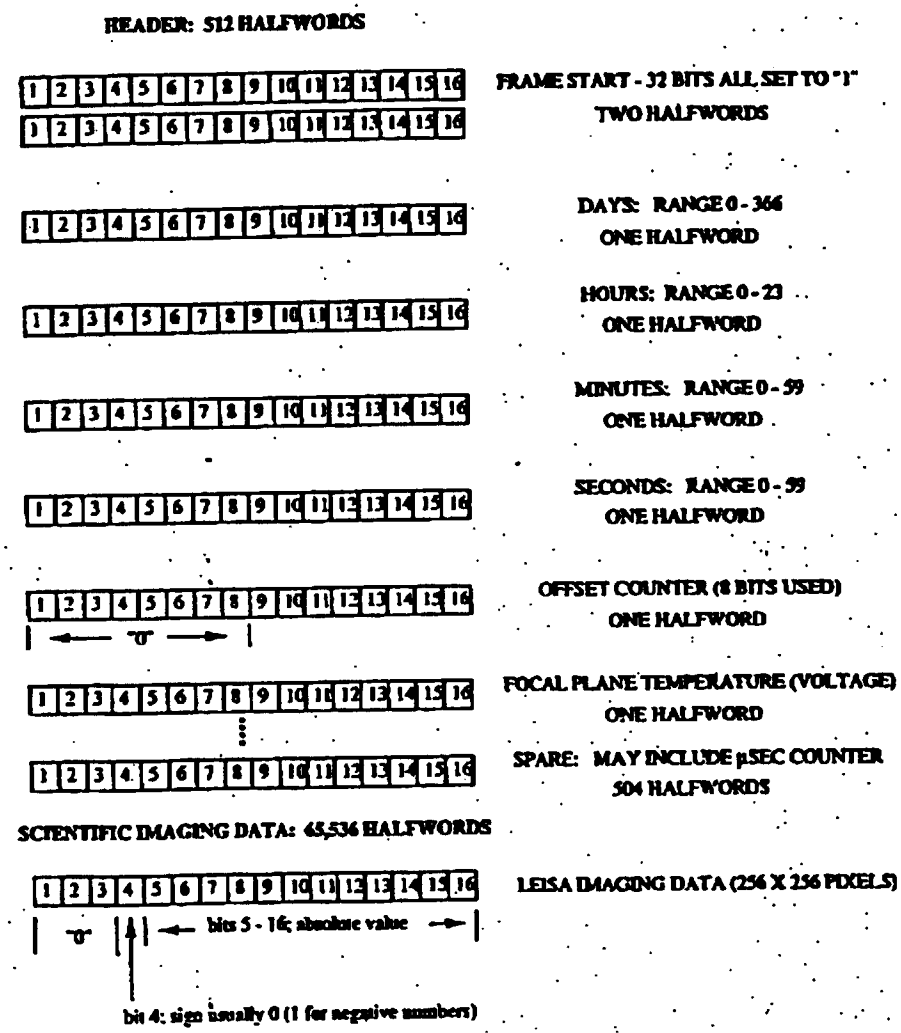
- On-Board Data Compression (Lossless and Lossy) is Planned. Format is Compatible with GSFC Compression Hardware and Software.

- Ground Processing Will Co-Register Frames and Produce Calibrated Spectral Maps (Data Cubes). Algorithms Being Developed at GSFC and University of Maryland, College Park.

- Further Ground Processing as Required by Science.

- On-Board Cloud Editing Plan TBD

SSR DATA FORMAT (EACH FRAME)



STATUS AND HOUSEKEEPING

- The Following Will be Sent Over the 1553 Bus
  - Echo of All Commands
  - Echo of Timing
  - Focal Plane Temperature (Possible - Still Open Question)
- Status Monitored by Other Subsystems
  - GEM LVPS (monitored by GEM)
  - Cryocooler (Monitored by PEA)
  - Optical Pointing Assembly (monitored by PEA)

COMMANDS

- Commands to be received over the 1553 Bus:

  1. Power <u>On</u> (GEM command)
  2. Set <u>Frame Rate</u>
  3. <u>Logic Reset</u>
  3. <u>Start</u> Data Stream
  4. <u>Stop</u> Data Stream
  5. Power <u>Off</u> (GEM command)

OPA COMMAND MODES

- Stationary View and Initial Pointing - Algorithm and Software from TRW

- Image Motion During Data Acquisition

  Off-Nadir Image Motion Compensation (Tracking) - Algorithm Already Supplied to TRW by GSFC

  Limb Scanning to Obtain Spectrum - Algorithm to be Supplied to TRW by GSFC

  Along Track Scan at Nadir - Algorithm to be Supplied to TRW by GSFC

TEST AND CALIBRATION PLAN

- Functional Tests of Prototype Optics Module and Cryocooler Will be Performed in a Vacuum Chamber at GSFC Propulsion Test Site.
- Vibration Tests of Prototype Hardware Will be Performed at GSFC in Bldg. 7 Facility on a Fast Turn-around Basis.
- Qualification Tests (T-V, Vib., EMI/EMC) Will be Performed at GSFC in Bldg. 7 Facility.
- Calibration of Flight Unit Will be Performed During Pre-Qualification Functional Tests
- Plan for System Level Tests to be Performed at Chantilly during Spacecraft Environmental Tests Will be Available by 5/15/95.

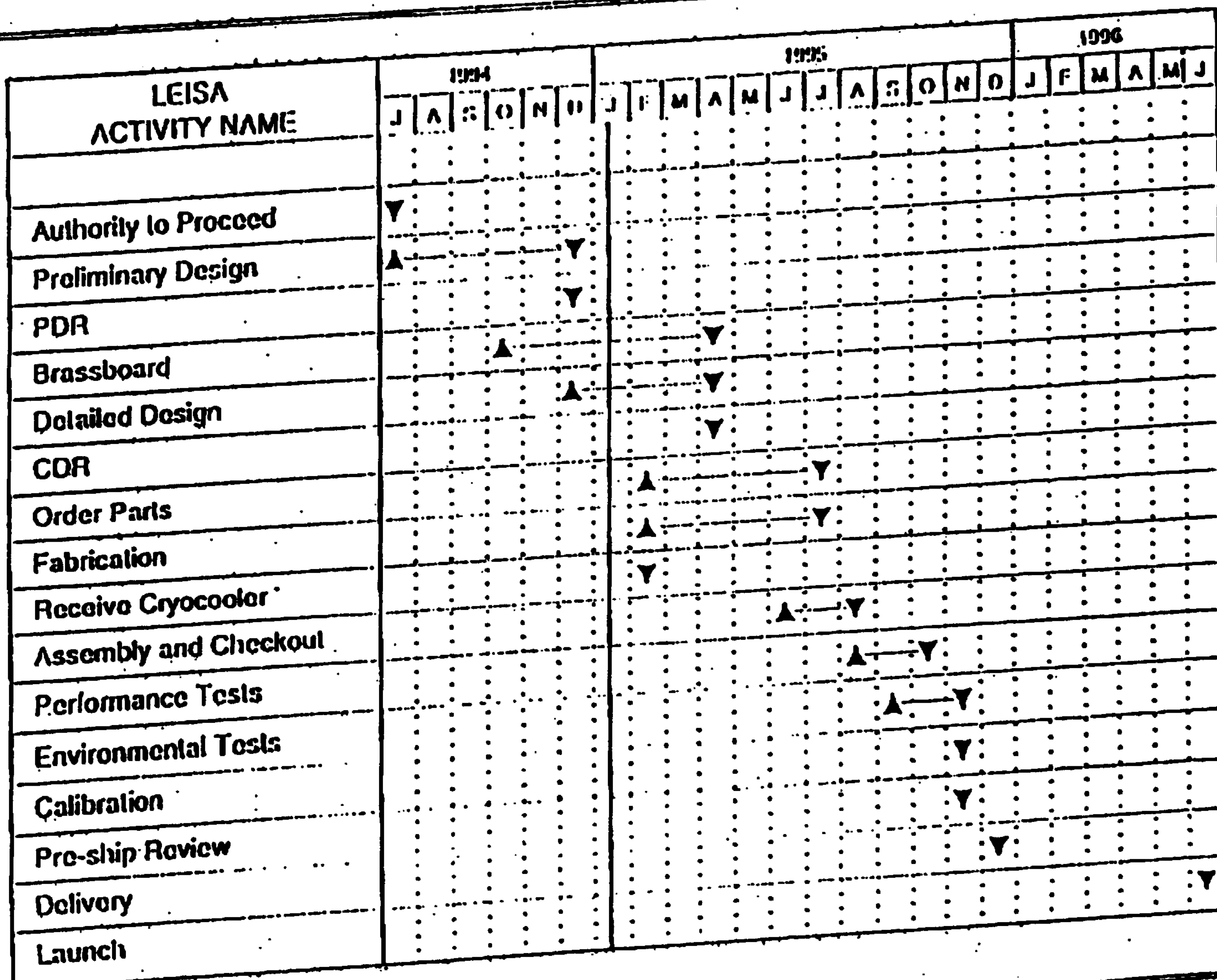
ISSUES

- Design of LASS Bracket to be Finalized, Including Thermal Sinking and and Mount to Spacecraft.
- Spacecraft Yaw Set Before Taking Data to Compensate for Earth's Rotation. Latitude Dependent.
- Optics Module and Focal Plane Require Thermal Stability During Observations. Stabilization Time TBD.
- On-board Cloud Editing Plan TBD.

KEY DELIVERABLE SCHEDULE

Activity	1995 Dates
Cryocooler received at GSFC	1/15
ICD signed	1/11
CDA	1/17-19
OPA algorithms specified	1/20
1553 simulator software received	3/15
SSR simulator boards and software received	3/15
LASS bracket (including radiator) received	4/15
Dual-port RAM received	5/1
System-level test plan delivered to Chantilly	5/15
OPA (or simulated mass) received at GSFC	10/1
Delivery to Chantilly	12/29

SCHEDULE


LEISA
ACTIVITY NAME
1994
J A S O N D
1995
J F M A M J J A S O N D
1996
J F M A M J
Authority to Proceed
Preliminary Design
PDR
Brassboard
Detailed Design
CDR
Order Parts
Fabrication
Receive Cryocooler
Assembly and Checkout
Performance Tests
Environmental Tests
Calibration
Pre-ship Review
Delivery
Launch

PAYLOADS & TECHNOLOGY DEMONSTRATIONS
UCB

J. Edelstein

Extreme Ultraviolet
Cosmic Background experiment

- Galactic astronomy,
- Cosmology,
- Upper atmospheric physics

Diffuse spectroscopy:

- 550 - 1050 Angstrom

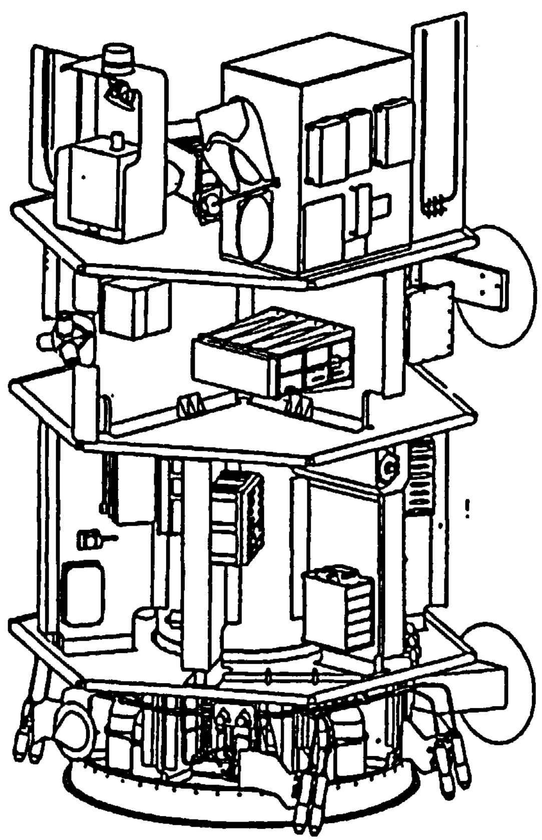
- Field of view 26 x 8 degrees

- Anti-sun pointing

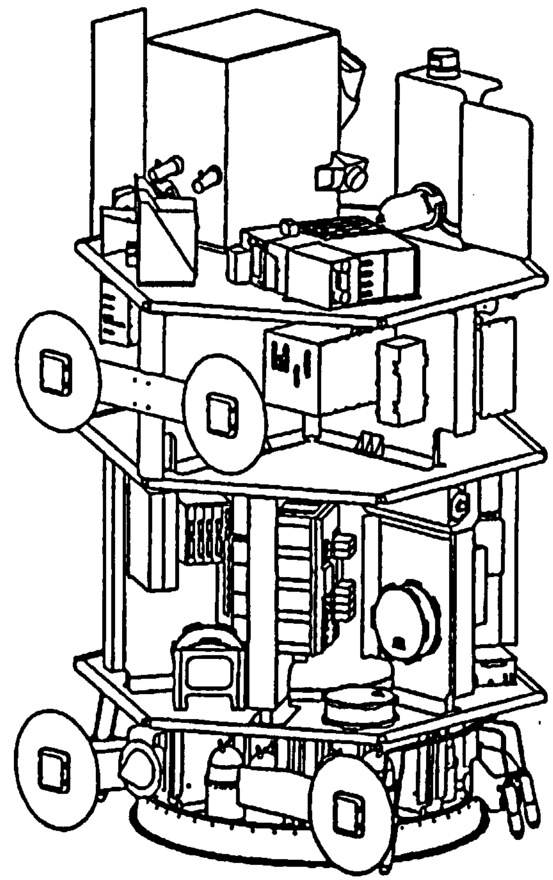
- Observing mode during eclipse only.

- Standby mode at all other times.

Spacecraft Configuration



NADIR FACE



ZENITH FACE

UCB Development Status

Documents:
- Contract signed
- ICD pending
- Reviewed FORD, Environmental Specs

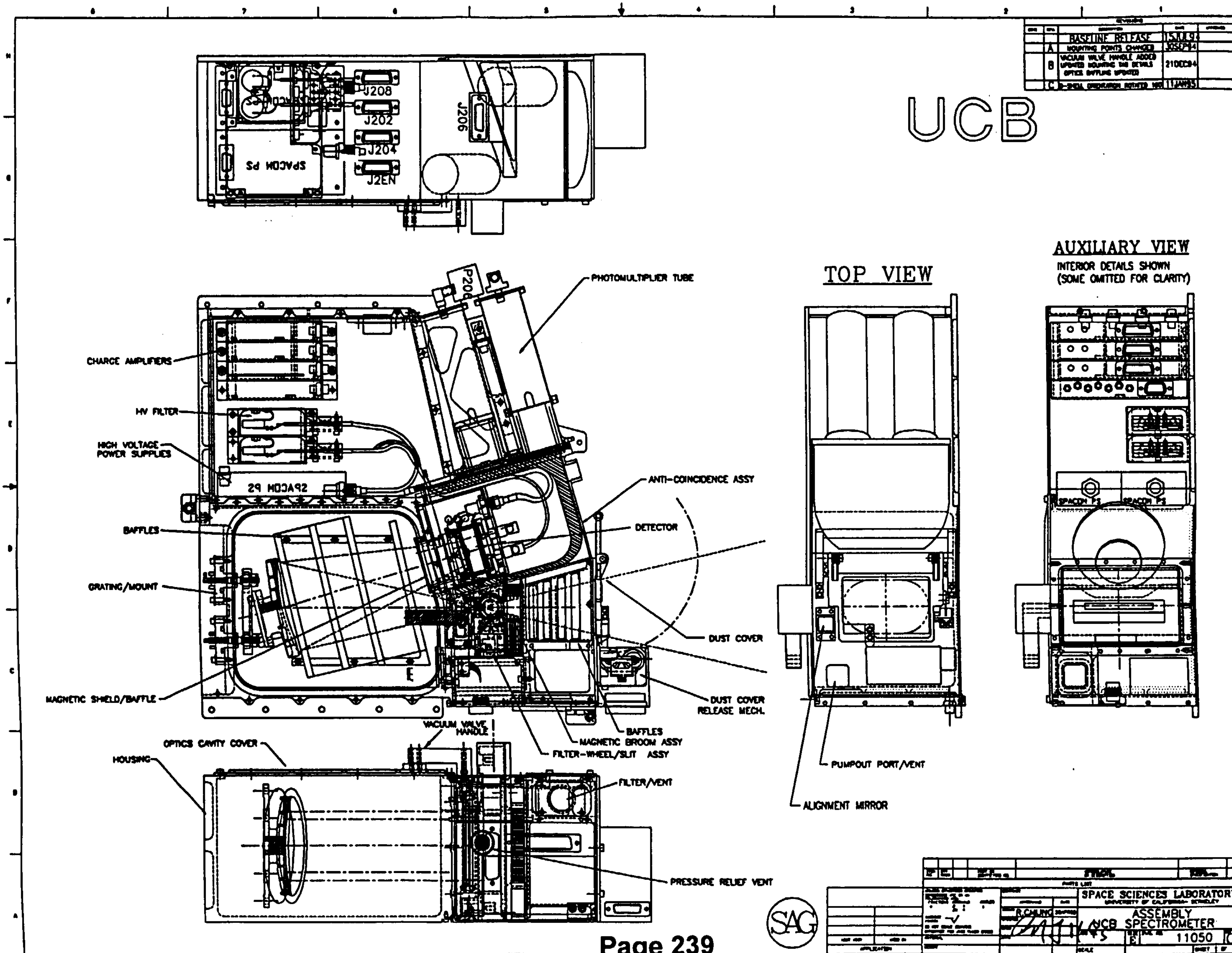
UC CDR's:
- Spectrograph Front End & Structure
- All mechanical system CDR's have been held
- Remaining CDR's:
  - 1553 S/C IF,
  - LV system,
  - UCB software

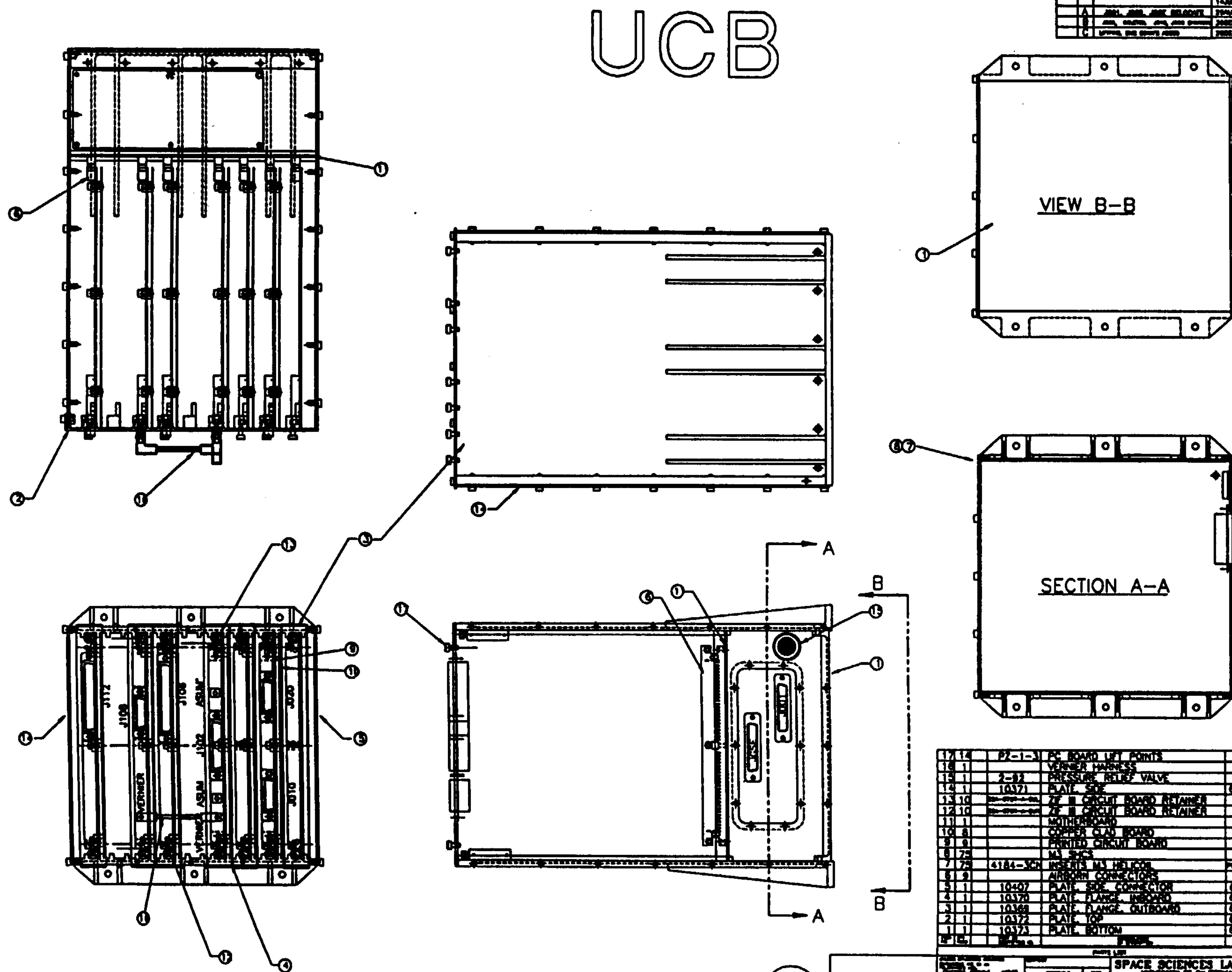
Flight Builds:
- PC boards (5 of 6)
- HV mixer
- Grating Assy

Performance Tests: Grating

Current Activities:
- Mechanical: Finalize drawings, Machining
- Electrical: Protoflight DSP, ADC, backplane
- Software: Implement uplink, Specification review

Long Leads:
- Received: Relays
- Pending: LV parts, 1553 parts


UCB
BASELINE RELEASE 15JUL93
A MOUNTING POINTS CHANGED 30SEP94
B VACUUM VALVE HANDLE ADDED UPDATED MOUNTING TAB DETAILS OPTICS BAFFLING UPDATED 21DEC94
C 11JAN95
J208
J202
J204
J2EN
J206
SPACOM PS
P206
PHOTOMULTIPLIER TUBE
CHARGE AMPLIFIERS
HV FILTER
HIGH VOLTAGE POWER SUPPLIES
ANTI-COINCIDENCE ASSY
DETECTOR
BAFFLES
GRATING/MOUNT
DUST COVER
MAGNETIC SHIELD/BAFFLE
DUST COVER RELEASE MECH.
VACUUM VALVE HANDLE
BAFFLES
MAGNETIC BROOM ASSY
FILTER-WHEEL/SLIT ASSY
OPTICS CAVITY COVER
HOUSING
FILTER/VENT
PRESSURE RELIEF VENT
TOP VIEW
PUMPOUT PORT/VENT
ALIGNMENT MIRROR
AUXILIARY VIEW
INTERIOR DETAILS SHOWN
(SOME OMITTED FOR CLARITY)
SPACOM P1
SPACOM P2
SAG
SPACE SCIENCES LABORATORY
ASSEMBLY
UCB SPECTROMETER
R.CHUNG
11050
C



17	14		P7-1-3	PC BOARD LIFT POINTS	303 SS
16	1			VERNIER HARNESS	VARIES
15	1		2-92	PRESSURE RELIEF VALVE	VARIES
14	1		10371	PLATE, SIDE	6061-T6 AL
13	10		[illegible]	ZIF III CIRCUIT BOARD RETAINER	VARIES
12	10		[illegible]	ZIF III CIRCUIT BOARD RETAINER	VARIES
11	1			MOTHERBOARD	VARIES
10	8			COPPER CLAD BOARD	VARIES
9	9			PRINTED CIRCUIT BOARD	VARIES
8	75			M3 SHCS	CRES
7	75		4184-3CN	INSERTS M3 HELICOIL	PHOSPHOR BRONZE
6	9			AIRBORN CONNECTORS	VARIES
5	1		10407	PLATE, SIDE, CONNECTOR	6061-T6 AL
4	1		10370	PLATE, FLANGE, INBOARD	6061-T6 AL
3	1		10369	PLATE, FLANGE, OUTBOARD	6061-T6 AL
2	1		10372	PLATE, TOP	6061-T6 AL
1	1		10373	PLATE, BOTTOM	6061-T6 AL

PARTS LIST

SPACE SCIENCES LABORATORY

UNIVERSITY OF CALIFORNIA - BERKELEY

ASSEMBLY
UCB ELECTRONICS BOX

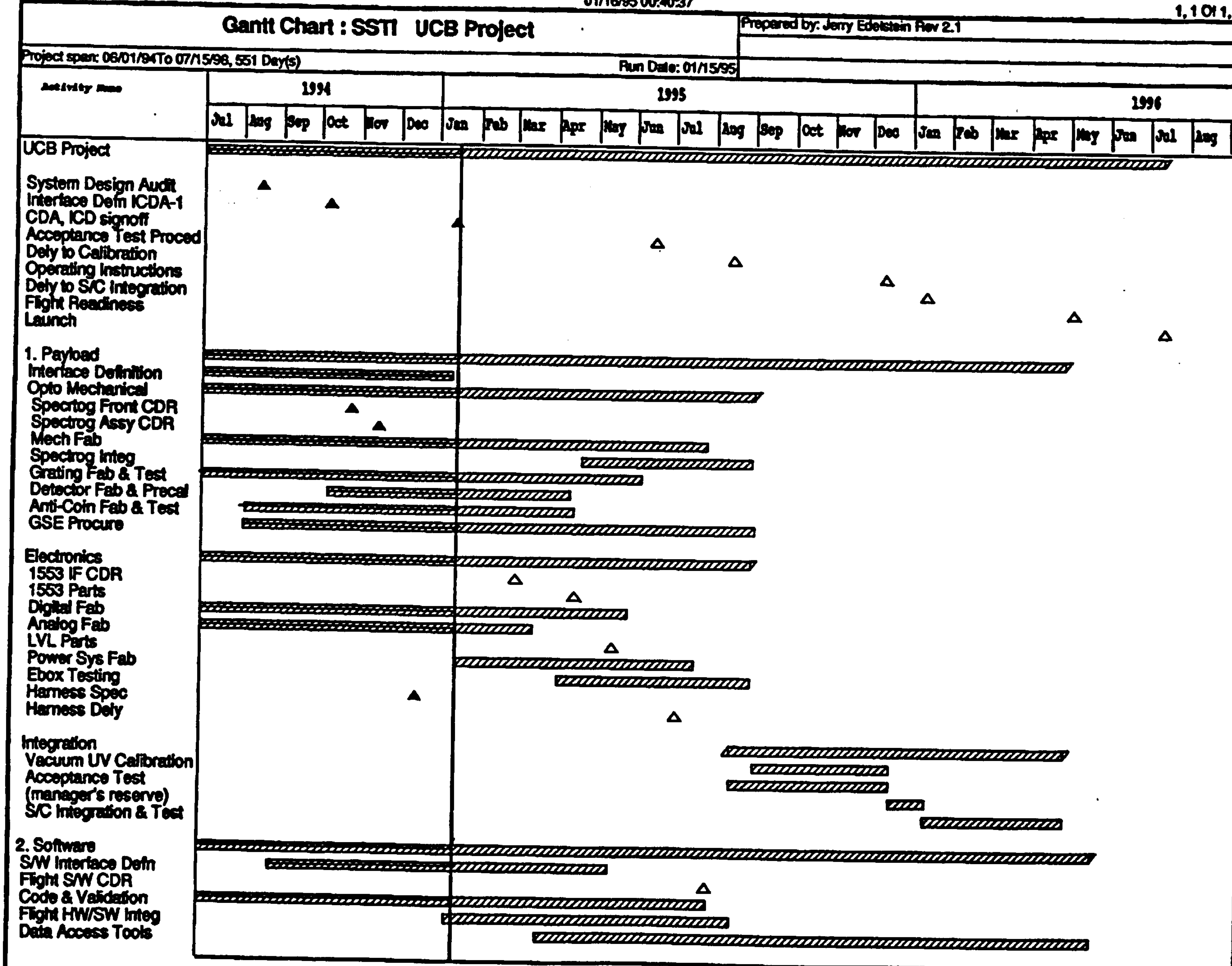
E 11051 C

R. CHUNG

SAC

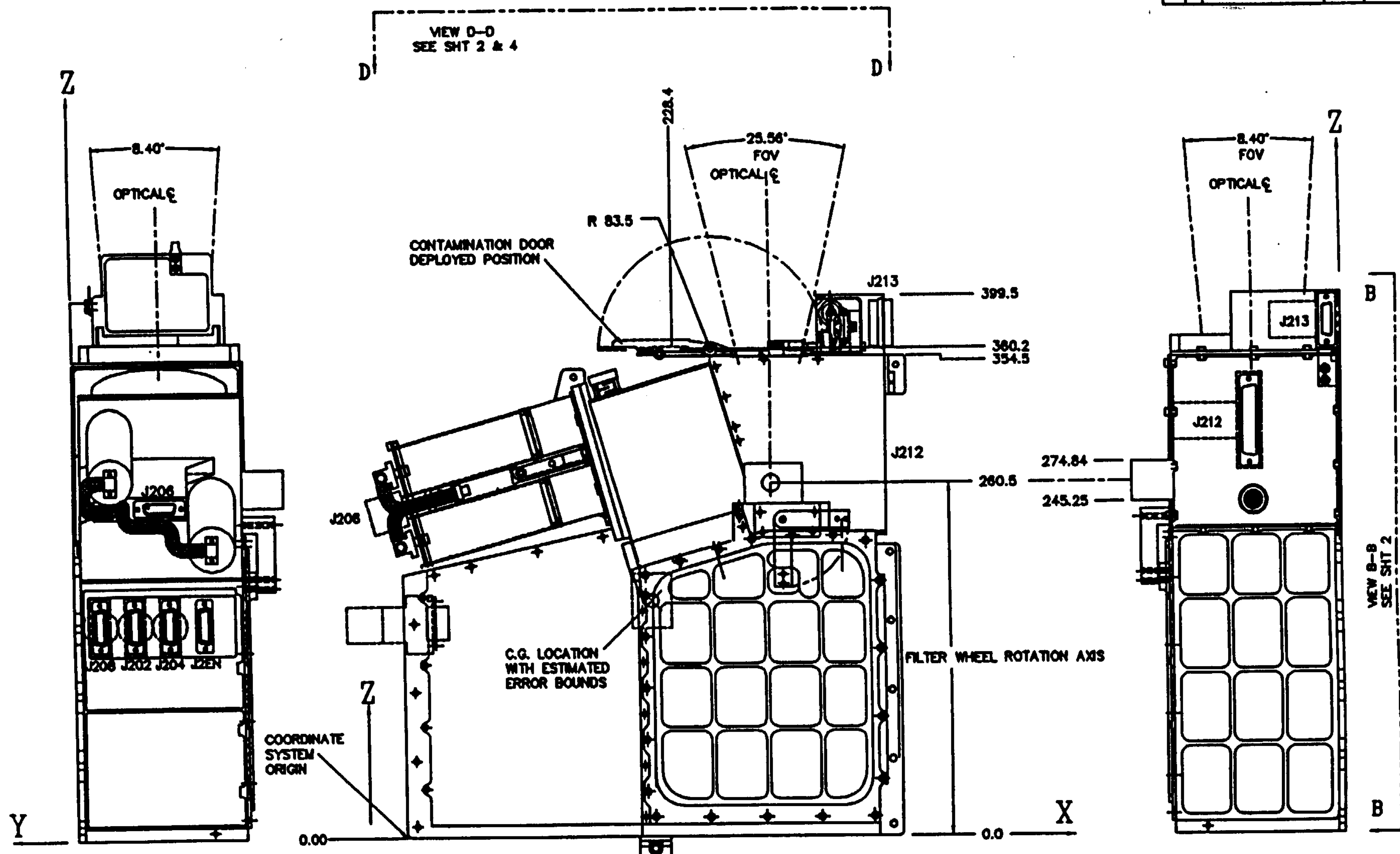
Page 240

A


Gantt Chart : SSTI UCB Project
Prepared by: Jerry Edelstein Rev 2.1
Project span: 06/01/94 To 07/15/96, 551 Day(s)
Run Date: 01/15/95
Activity Name
1994
1995
1996
Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
UCB Project
System Design Audit
Interface Defn ICDA-1
CDA, ICD signoff
Acceptance Test Proced
Dely to Calibration
Operating Instructions
Dely to S/C Integration
Flight Readiness
Launch
1. Payload
Interface Definition
Opto Mechanical
Spectrog Front CDR
Spectrog Assy CDR
Mech Fab
Spectrog Integ
Grating Fab & Test
Detector Fab & Precal
Anti-Coin Fab & Test
GSE Procure
Electronics
1553 IF CDR
1553 Parts
Digital Fab
Analog Fab
LVL Parts
Power Sys Fab
Ebox Testing
Harness Spec
Harness Dely
Integration
Vacuum UV Calibration
Acceptance Test
(manager's reserve)
S/C Integration & Test
2. Software
S/W Interface Defn
Flight S/W CDR
Code & Validation
Flight HW/SW Integ
Data Access Tools

NOTES:
1. INTERPRET PER ANSI Y14.5M-1982.
2. EMI BACKSHELLS SHOWN WITH DASHED LINES.

	BASELINE RELEASE
A	Y-AXIS CORRECTED SHEET 1 ONLY
B	MOUNTING POINTS CHANGED
C	
D	

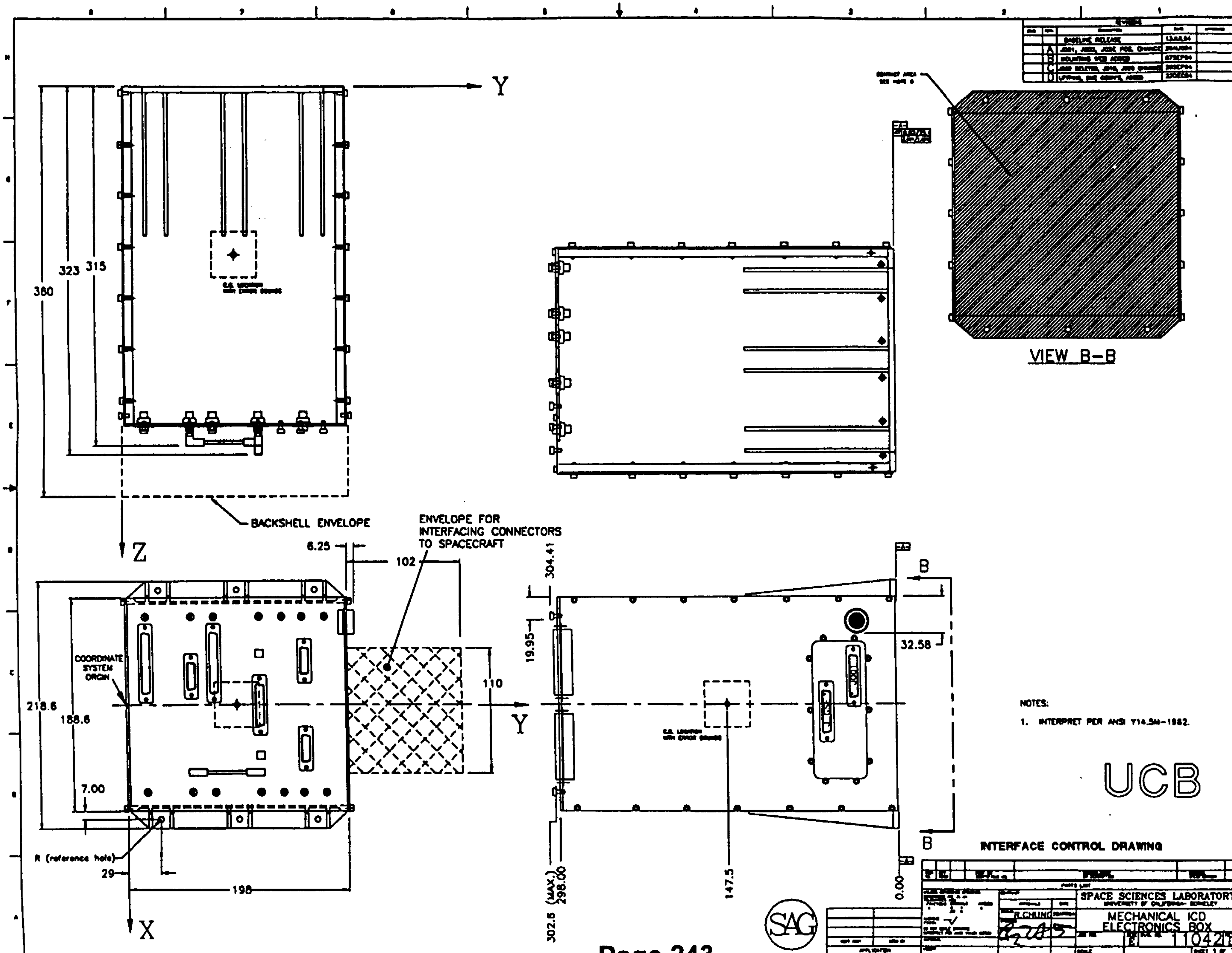


INTERFACE CONTROL DRAWING

SPACE SCIENCES LABORATORY

MECHANICAL ICD
SPECTROMETER

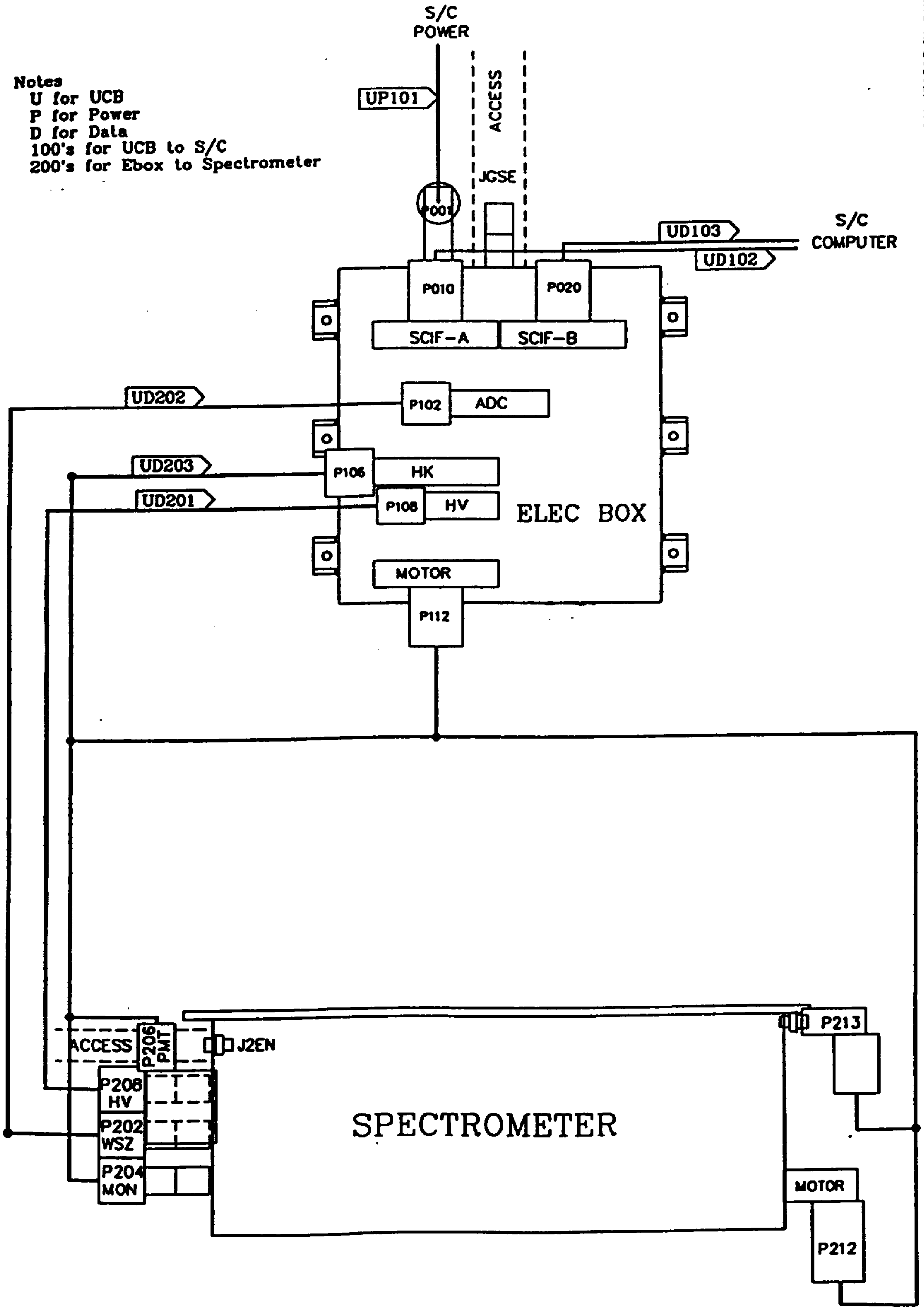
11041 D



Y
360
323
315
BACKSHELL ENVELOPE
Z
ENVELOPE FOR INTERFACING CONNECTORS TO SPACECRAFT
6.25
102
110
COORDINATE SYSTEM ORIGIN
218.6
188.6
7.00
R (reference hole)
29
198
X
Y
304.41
19.95
32.58
B
147.5
302.6 (MAX.)
298.00
0.00
VIEW B-B
NOTES:
1. INTERPRET PER ANSI Y14.5M-1982.
UCB
INTERFACE CONTROL DRAWING
SPACE SCIENCES LABORATORY
MECHANICAL ICD
ELECTRONICS BOX
R.CHUNG
E
110428

CONNECTOR/HARNESS LAYOUT
11045 Rev. B
R.CHUNG 1 Dec 94

Notes
U for UCB
P for Power
D for Data
100's for UCB to S/C
200's for Ebox to Spectrometer



UCB Performance Status

Performance Metrics:

<u>Bandpass</u>

Coverage	55.0 - 105.0 nm
Prime	58.5 - 95.0 nm

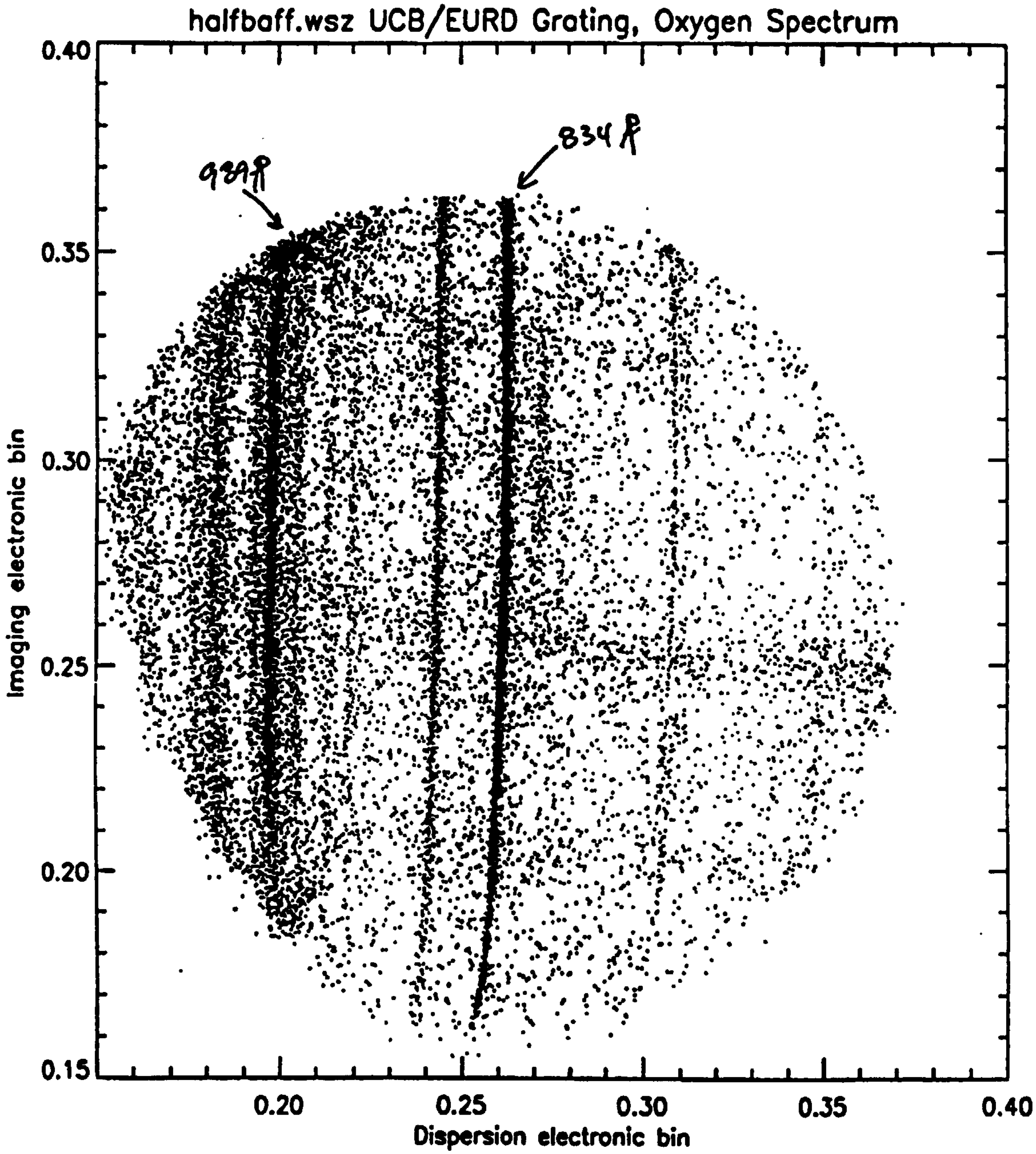
<u>Sensitivity, Diffuse Line Emission</u>
(photon/sec/cm^2/sr, 100 Hours Obsv)

Goal	Success	S.O.P
200	2,000	20,000 (400 hrs)

<u>Spectral Resolution</u>
0.5 nm / 0.7 / 3.0

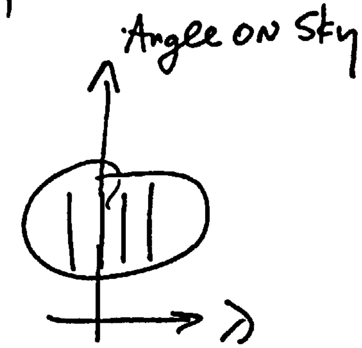
Performance Factors:

Bandpass:	
Grating dispersion	Verified
Detector active area	Verified
Sensitivity, Background:	
Detector background	Verified
Anti-coincidence	Verified
Grating scattering	Verified
Geocoronal activity	as found in orbit
Sensitivity, Signal:	
Filter transmission	TBD, samples verified
Grating efficiency	Verified
Grating reflectivity	TBD
Detector efficiency	TBD, samples verified
Integration time	as per orbit
Resolution:	
Grating resolution	Verified
Detector resolution	Verified
Analog performance	Verified



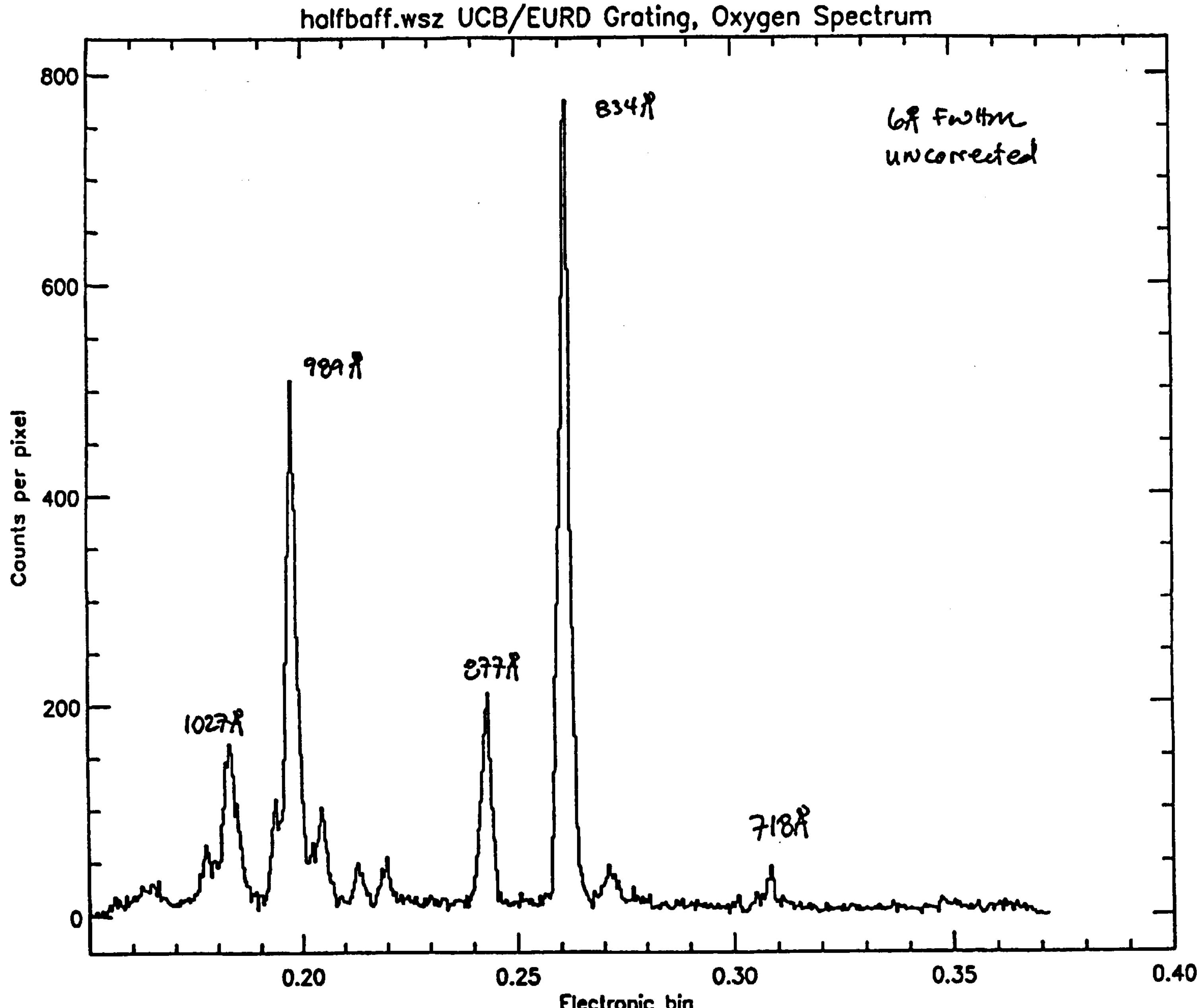
Detector
Image

UCB
First Light
Grating
Performance
Test



UCl

Spectrum



1 dec 94 electron

Payload Development Testing

- Subsystems Qualification
  - Detector Assy
  - Slit Wheel Assy
  - Contamination Cover Assy
- 1553 Simulator check

Payload Acceptance Testing

- Mass, CG, footprint
- Random Vibration
- Thermal Cycle (8 X, HV dummy load)
- Vacuum Thermal Cycle (4 X, HV live sensor)
- EMI/EMC
- EUV Performance Calibration

S/C Integration & Test

Interface
- Mounting / Alignment
- Electrical Lines & Levels

Commanding
- Discrete Lines (DSP selection)
- S/C Power
- UCB command uplink
- S/C commands (time, safing)
- UCB S/W uplink

Data
- H&S data
- S&E data
- End to End live data test (vacuum)

Digital Interface *(TBD)*
- Commands from UCB to TRW by PC floppy
- H&S data capture by TRW EWS, transfer to UCB by floppy
- Science Data transfer to UCB by PC floppy or Ethernet

Launch Site Integration & Test

Backfill Line installation

Systems checkout (~10 min)
- Power On Sequence
- Self-Stimulated data stream
- Power off Sequence

RED/GREEN TAG remove/install

Backfill Line removal

SOCC Integration & Test

H&S Data displays

Command procedure

Data aquistion

Communications protocol

Archive Integration & Test

UCB Command submission

UCB Data archive

Outsanding Issues

1553B interface specification:

Exact description of the 1553-bus event sequence.
All 1553 activity that affects UCB (retrys, etc.)
- UCB Telemetry to S/C
- UCB ground commands
- S/C commands (time broadcast)

1553B electrical parts

Driver / Reciever chip finalize/order
Transform type finalize/order

Power system performance

Eclipse +28V ripple specificaton

Spectrograph Mounting

Optically baffled surfaces near FOV

Contamination Control

EUV optics are
an ORDER OF MAGNITUDE more sensitive
to organic (NVR) contamination than visible optics (~ 1/λ).

NVR contamination:

After 1 year in orbit, at Filter Wheel:
- 150 ng/cm^2
- 15 Angstrom of C:
- 25% reflectivity loss (Grating)
- 30% transmission loss (Filters)

S/C & Vehicle NVR concerns:

Outgassing areas near FOV
- Harness insulation
- Backshell potting
- MLI materials (waxed threads, spacers)
- MLI venting

Fairing separation blowby or residue

Minimizing NVR

- Optics cavity shuttered for ground activities
- N_2 backfill until as late as availble on stand
- In orbit outgassing period
- One-time deploy contamination cover
- Extend/repeat Heating as allowed by S/C resources

PAYLOADS & TECHNOLOGY DEMONSTRATIONS

Recorder Interface Module (RIM)

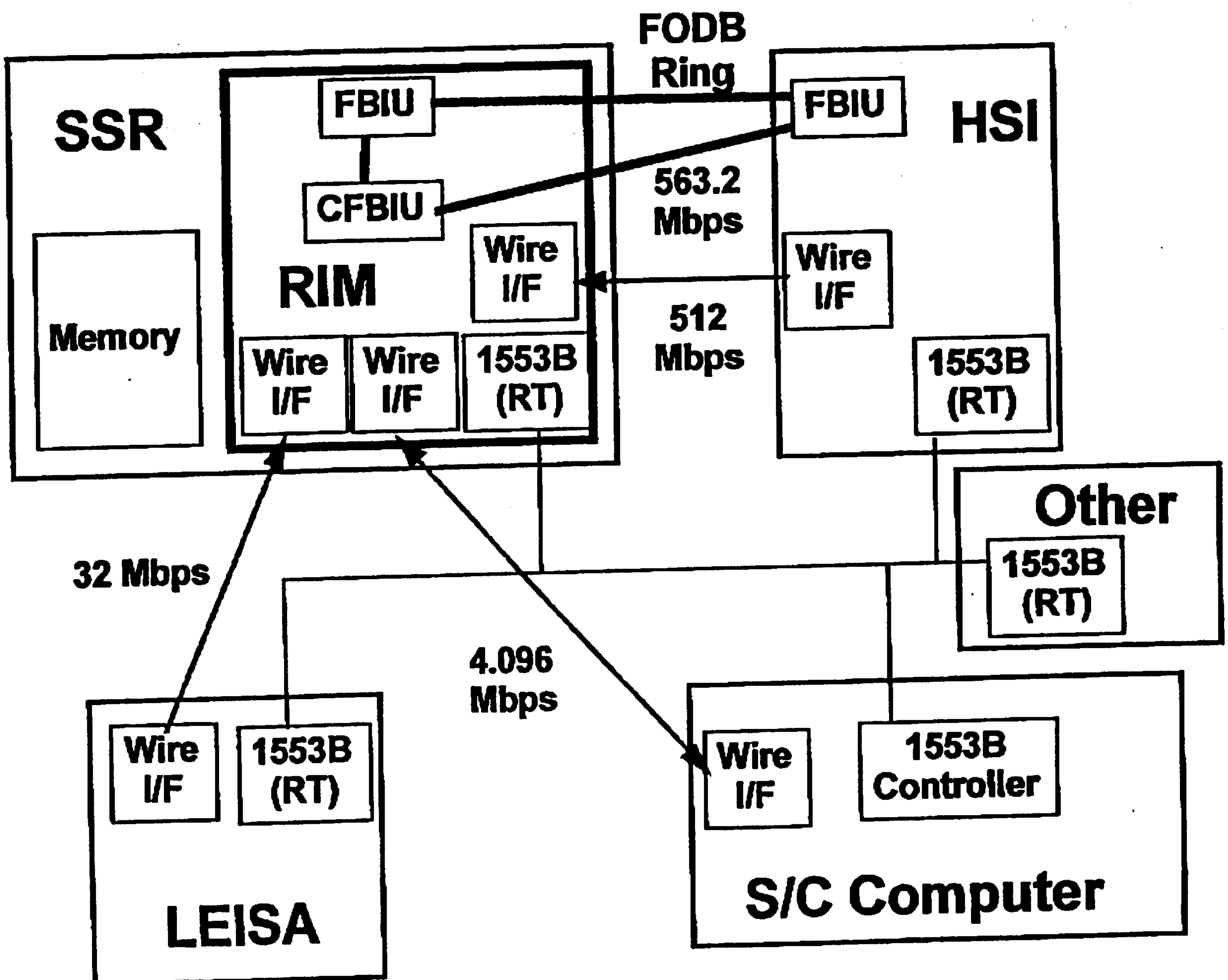
P. Hayes

Recorder Interface Module (RIM) Purpose

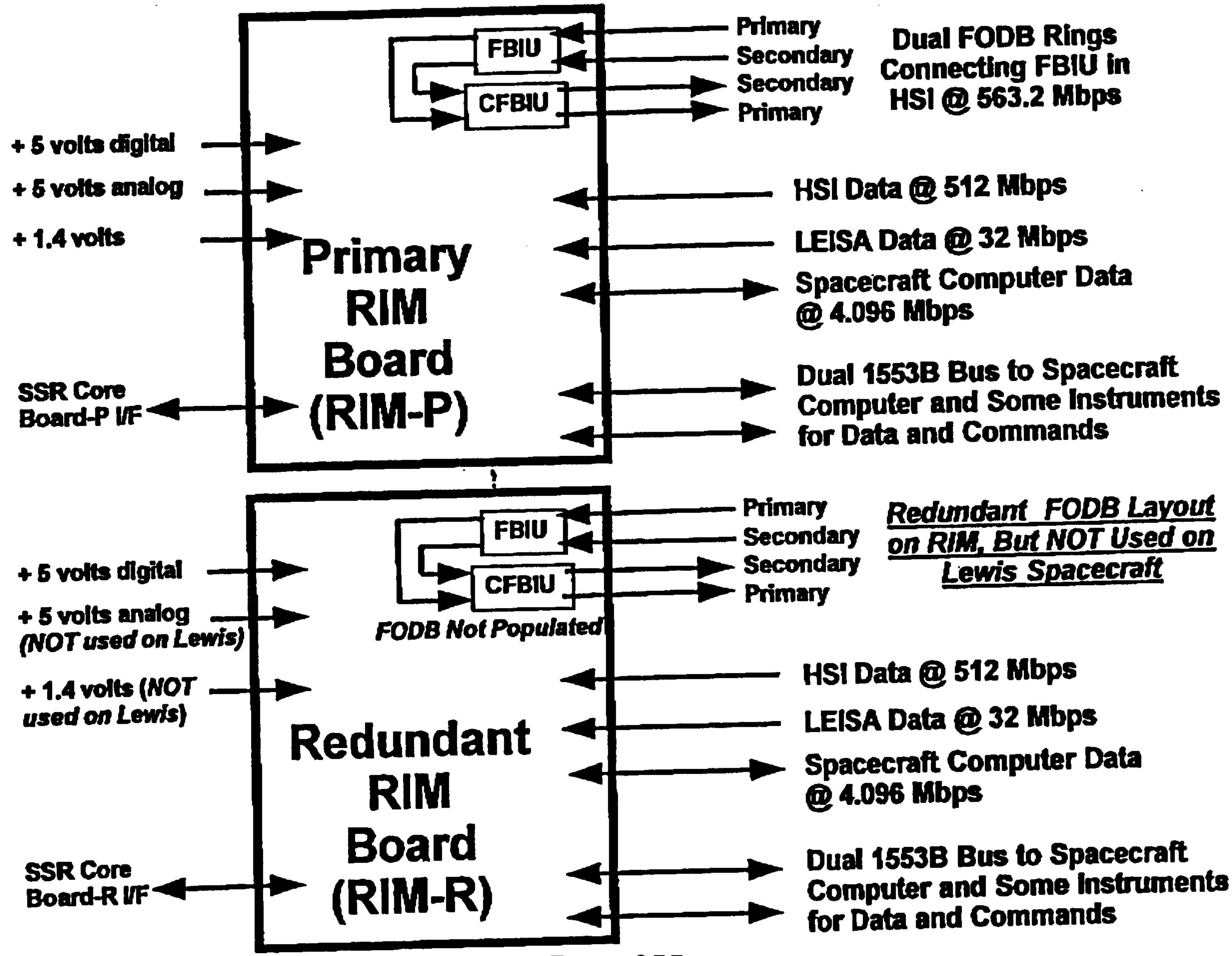
A critically-located interface board providing multiple interfaces for the onboard Solid State Recorder (SSR), and thus, facilitating data storage for the SSTI Lewis spacecraft. RIM features:

1) a low-speed 1553B bus interface for both commands and data
2) wire data interfaces to the spacecraft computer, LEISA, and HSI
3) a high-speed fiber optic data bus (FODB) interface to the HSI to support TRW's FODB experiment
4) interface to SSR core board for 8051 control and data routing

RIM Location in Lewis Architecture (Partial)



RIM's Redundant Architecture



January, 1995 Design/Plan Changes

- **RIM to be 2 boards rather than single board**
  - 2-sided, single layout for 10 in. X 6 in. board
  - Redundant board not populated with FODB section

- **Separate power for FODB section**
  - Enable turning FODB OFF if degradation, and maintaining use of other interfaces on Priomary board
  - Under study by LaRC team

- **Locate +1.4 volt converter on RIM board**
  - FODB is only use in SSR
  - Under study by LaRC team

- **TRW to supply H-frame to LaRC for mounting RIM boards**
  - Good protection for FODB cables, connectors
  - Saves fixture development at LaRC

- **Resolved Environmental Tests**
  - Thermal cycle only test required by TRW
  - LaRC mgm't & review panel desires vibration & thermal cycle for product integrity tests
  - TRW & LaRC agree on planned tests

Test Approach and Plans

- **Engineering Model functional testing**
  - Test FPGAs (2 designs) to verify functionality
  - Test complete RIM functionality with developed firmware
  - Verify test procedures to be used for Flight Unit

- **Engineering Model integration testing with SSR @ TRW**
  - Debugging to ease later Flight Unit integration

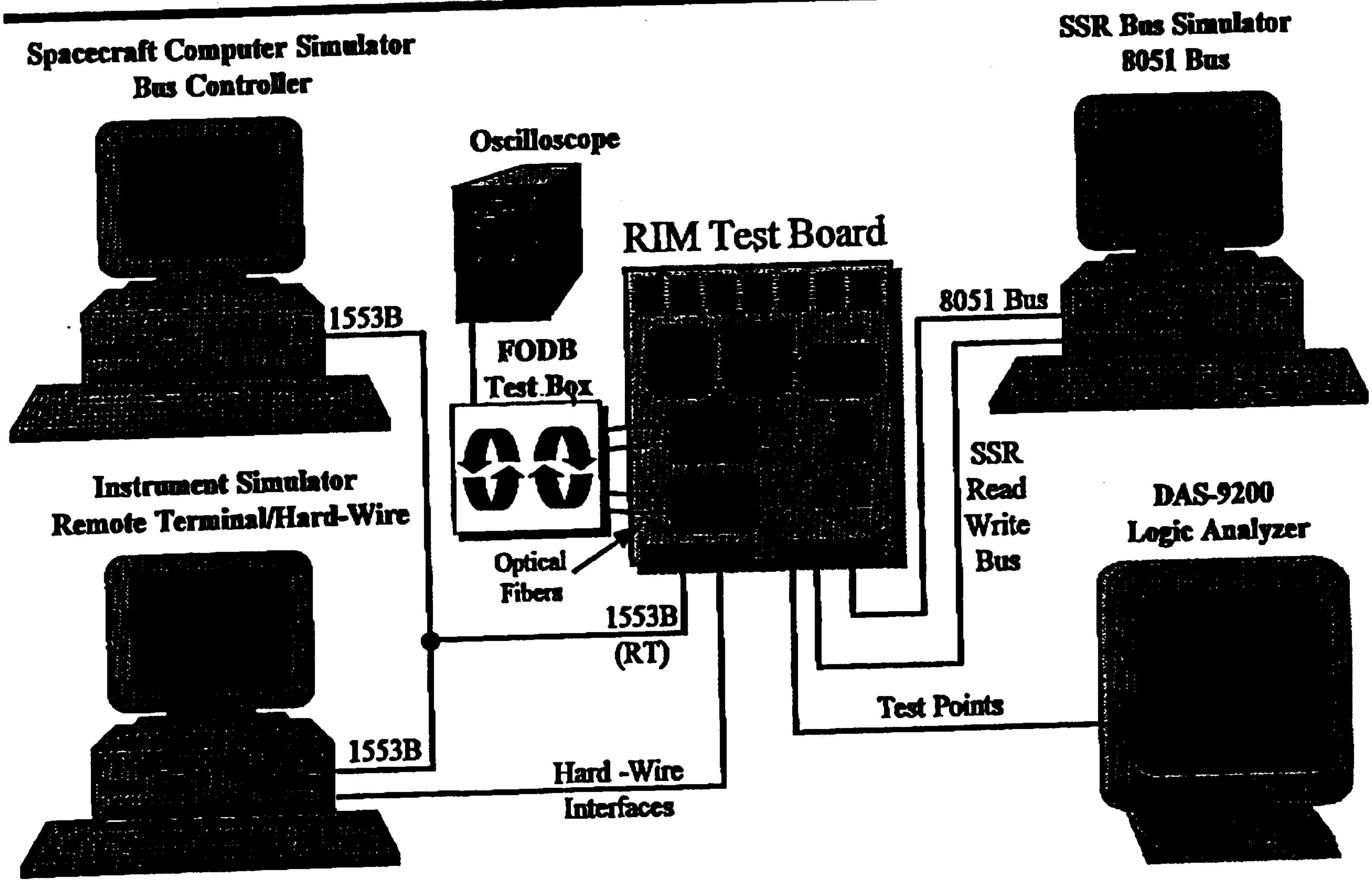
- **Flight Unit functional testing**
  - Use same test setup as for Engineering Model
  - Before and after environmental tests

- **Flight Unit environmental testing**
  - Thermal cycle (non-powered)
  - Vibrational test on 3 axes with performance test of 1553B
  - Thermal vacuum flight simulation test (operational during transition from atmosphere to vacuum; operational over temperature range)
  - Performance tests keep FODB internal parts below 75 deg C

- **Flight Unit integration testing in SSR @ TRW**

LaRC

Recorder Interface Module
Test Setup



RIM Development Progress

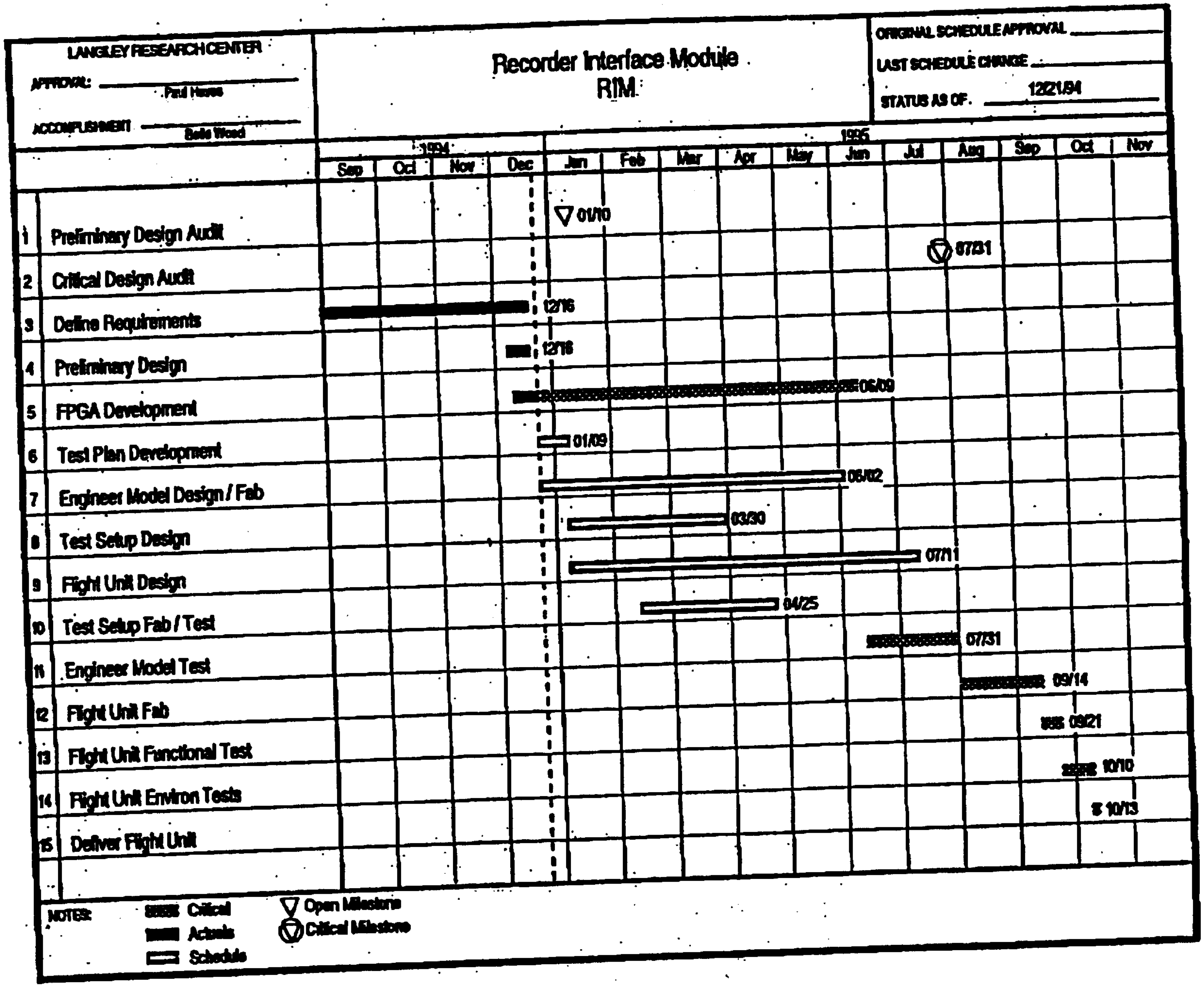
- **Developed RIM Requirements Document**
  - Draft 11/8/94 defining interfaces and functionality
  - Many TBDs but no major disagreements between TRW & LaRC

- **FPGA Minispec Written**
  - Draft 11/23/94; revisions agreed to & in typing
  - Two FPGA designs initiated 12/94

- **Product Assurance Plan Drafted 10/11/94**
  - Comments received and revision near completion

- **Preliminary Design Audit (PDA) held at LaRC 1/10/95**
  - Preliminary schematic, layout, & preliminary parts selection
  - Reliability estimate of .925 for 5 years provided to TRW
  - Major action items resolved in post-PDA meeting with TRW

- **Recent Design Changes (Jan, 1995)**
  - Some under study



LANGLEY RESEARCH CENTER
APPROVAL: Paul Hesse
ACCOMPLISHMENT: Bella Wood
Recorder Interface Module
RIM
ORIGINAL SCHEDULE APPROVAL
LAST SCHEDULE CHANGE
STATUS AS OF: 12/21/94
1994
1995
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
1 Preliminary Design Audit
2 Critical Design Audit
3 Define Requirements
4 Preliminary Design
5 FPGA Development
6 Test Plan Development
7 Engineer Model Design / Fab
8 Test Setup Design
9 Flight Unit Design
10 Test Setup Fab / Test
11 Engineer Model Test
12 Flight Unit Fab
13 Flight Unit Functional Test
14 Flight Unit Environ Tests
15 Deliver Flight Unit
01/10
07/31
12/16
12/16
06/09
01/09
06/02
03/30
07/11
04/25
07/31
09/14
09/21
10/10
10/13
NOTES:
Critical
Actuals
Schedule
Open Milestone
Critical Milestone

LaRC

Recorder Interface Module

Requirements vs. Capabilities

PARAMETERS	REQUIREMENT			CAPABILITY			UNITS	NOTES
	MIN	NOM	MAX	MIN	NOM	MAX		
DATA RATES								
HSI- Fiber (burst)	512			563.2	563.2	563.2	Mbps	FO Data burst
HSI - Wire		512			512	768	Mbps	
LEISA - Wire		32			32	96	Mbps	
SC - Wire		4.096			4.096	24	Mbps	
1553B - Wire		1.0			1.0	1.0	Mbps	
SIZE								
Length		6			6		Inches	
Width		10			10		Inches	
Height					0.8		Inches	
Weight					4		Pounds	Design @ PDA
POWER								
Primary				22.81		34.9	Watts	Design @ PDA
Redundant				9.29		17.64	Watts	Design @ PDA
VOLTAGES								
Digital	4.75	5.0	5.25	4.75	5.0	5.25	Volts	
Analog	4.75	5.0	5.25	4.75	5.0	5.25	Volts	
ECL	1.3	1.4	1.5	1.3	1.4	1.5	Volts	Design @ PDA
TEMPERATURE								
Operating Test	-29		+39	-29		+39	°C	w/ FODB
Operating Test	-29		+66	-29		+66	°C	wo/ FODB
Non-operating	-34		+71	-34		+71	°C	

Recorder Interface Module

Requirements. Capabilities, Verification

Requirement	Capability	Verification Plan
Selectable Input Interfaces:	Select one; 1553B listens continually	Functional test
HSI -fiber optic for 512 Mbps data (min)	Data I/O ring burst - 563.2 Mbps data	"
HSI - wire w/32 parallel lines	Comply	"
LEISA - wire w/4 parallel lines	Comply	"
SC Computer - serial wire	Comply	"
1553B - remote terminal	Comply	Use of TRW sim code
Selectable output interfaces:	Select one	Functional test
SC Computer - serial wire w/dual outputs	Comply	"
1553B - remote terminal	Comply	Use of TRW 1553B sim code
Simultaneous write and read	Comply, via one input and one output; 1553B receives and buffers input continuously	Functional test
FODB - ring control	Comply	Functional test
FODB - health and status	Information provided for SSR telemetry	"

Recorder Interface Module

Requirements. Capabilities, Verification (Con'td)

Requirement	Capability	Verification Plan
1553B operation during launch	Comply	Performance test - vibration & thermal vacuum
Operation over temperature range of -29 to +66 deg C	Comply; with restricted temperature testing when FODB is ON)	Thermal vacuum tests
Redundant architecture	Primary and redundant boards	TRW's SSR integration
Reliability GOAL of .96 for 5 years/board	Preliminary estimate - .925 for 5 years	

PAYLOADS & TECHNOLOGY DEMONSTRATIONS GEM/SLAM

P. Luers

SSTI Lewis Critical Design Audit

Goddard Electronics Module (GEM)

Philip Luers
Goddard Space Flight Center
Flight Data Systems Branch
Code 735

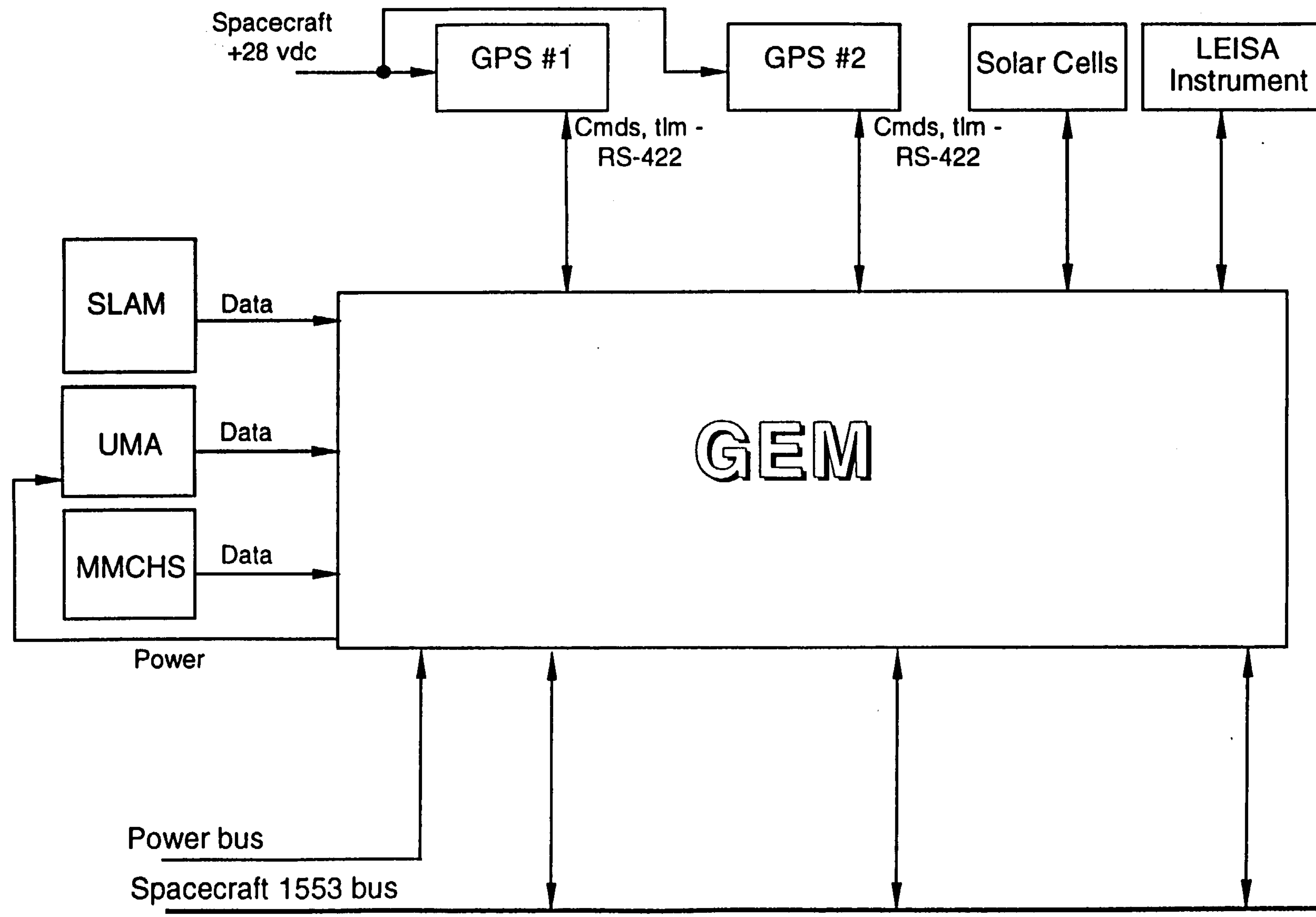
17-19 January 1995

GEM Requirements

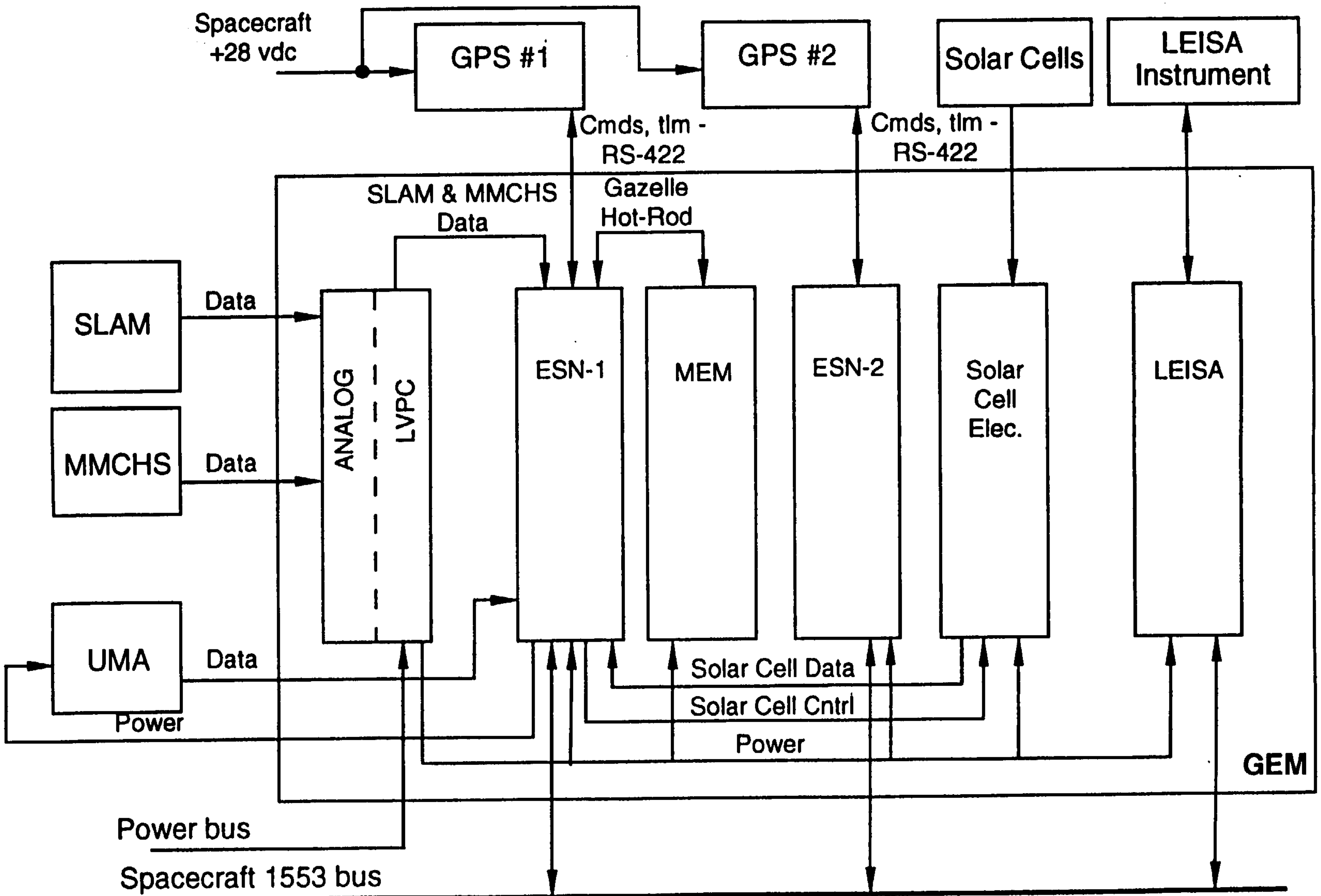
- Functional
  - receive, format, store, and transmit data and/or provide power for the following Lewis experiments:
    - » Advanced Solar Cell Experiment (ASCE)
    - » Systems Launch & Acoustics Module (SLAM)
    - » Metal Matrix Composite Heat Strap (MMCHS)
    - » Linear Etalon Imaging Spectral Array (LEISA)
    - » Global Positioning System (GPS)
    - » Micromachined Accelerometer (UMA) (Univ. of Cinn.)

NASA/GSFC
Flight Data Systems Branch
Code 735

GEM Interfaces

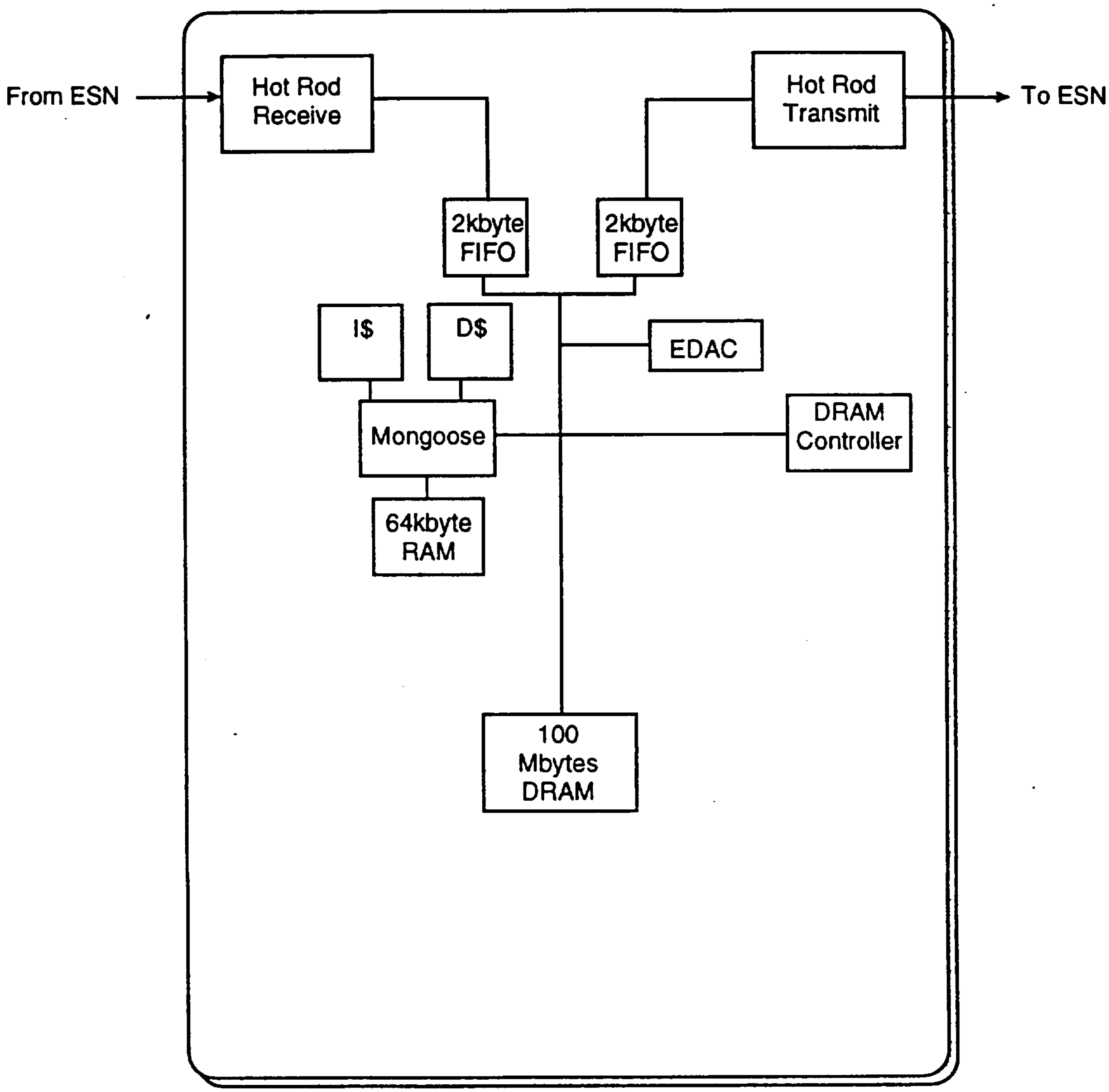


GEM CONFIGURATION

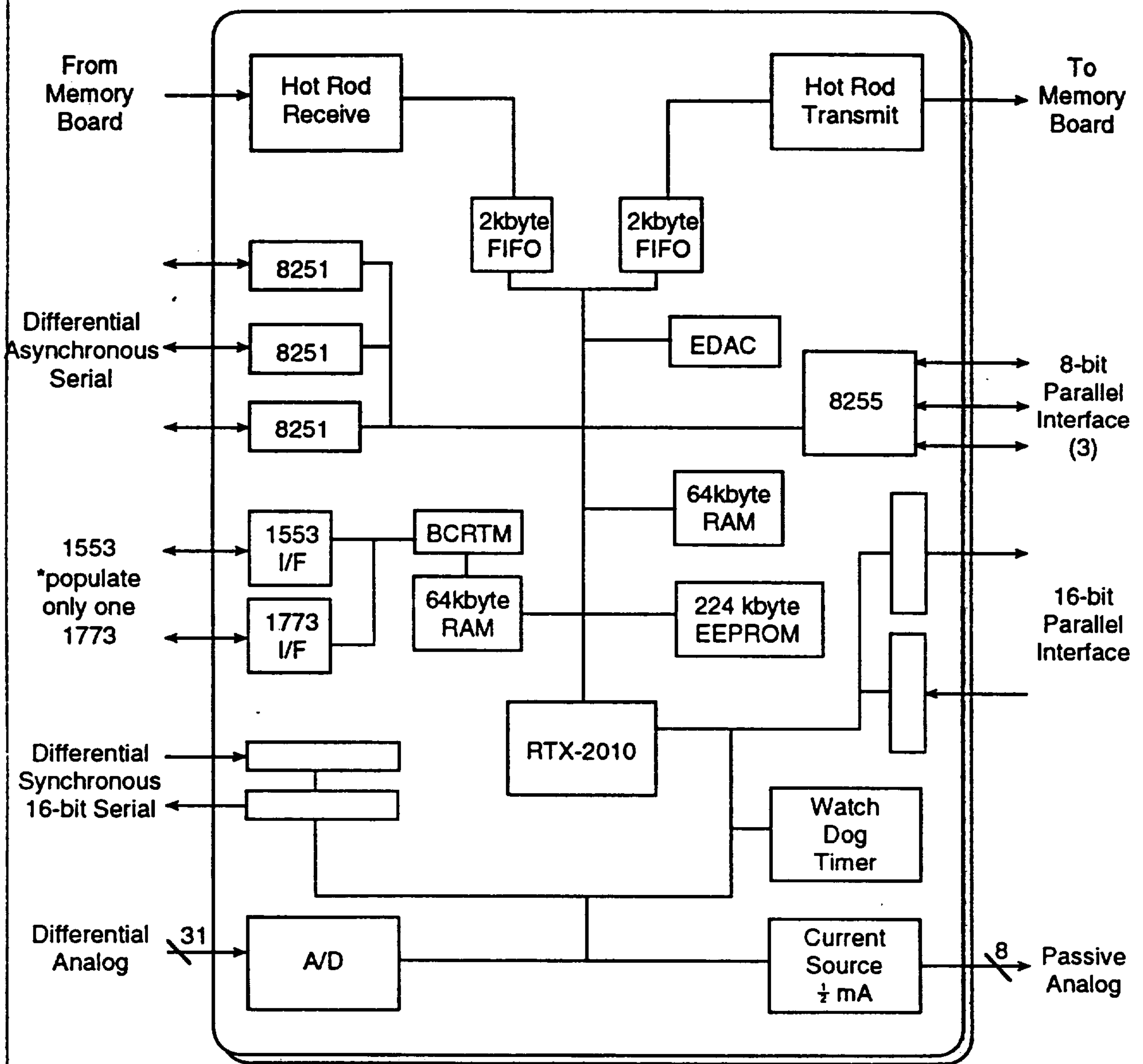


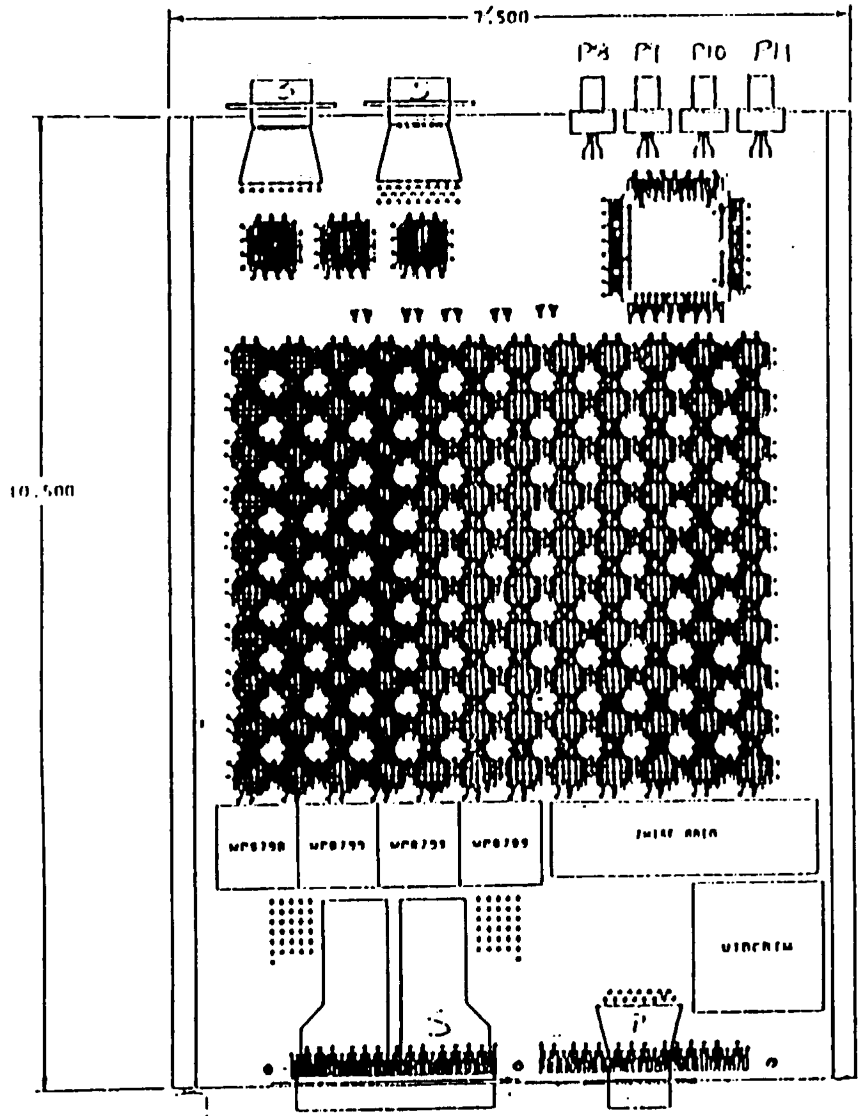
NASA/GSFC
Flight Data Systems Branch
Code 735

GEM/SSTI DRAM Block Diagram

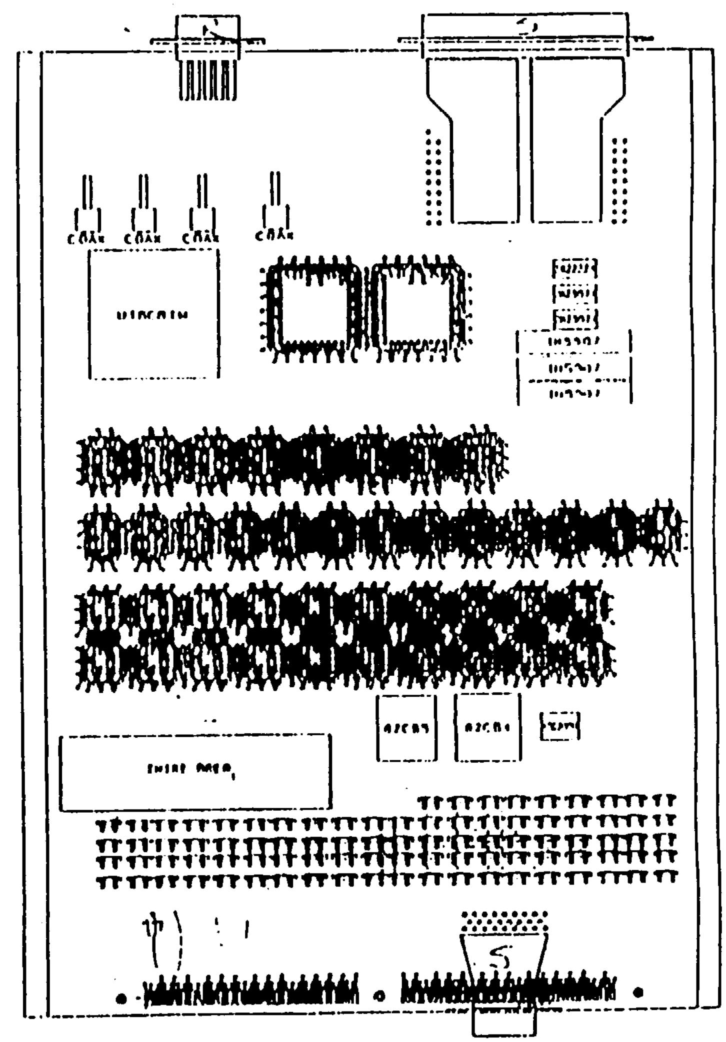


GEM/SSTI ESN Block Diagram

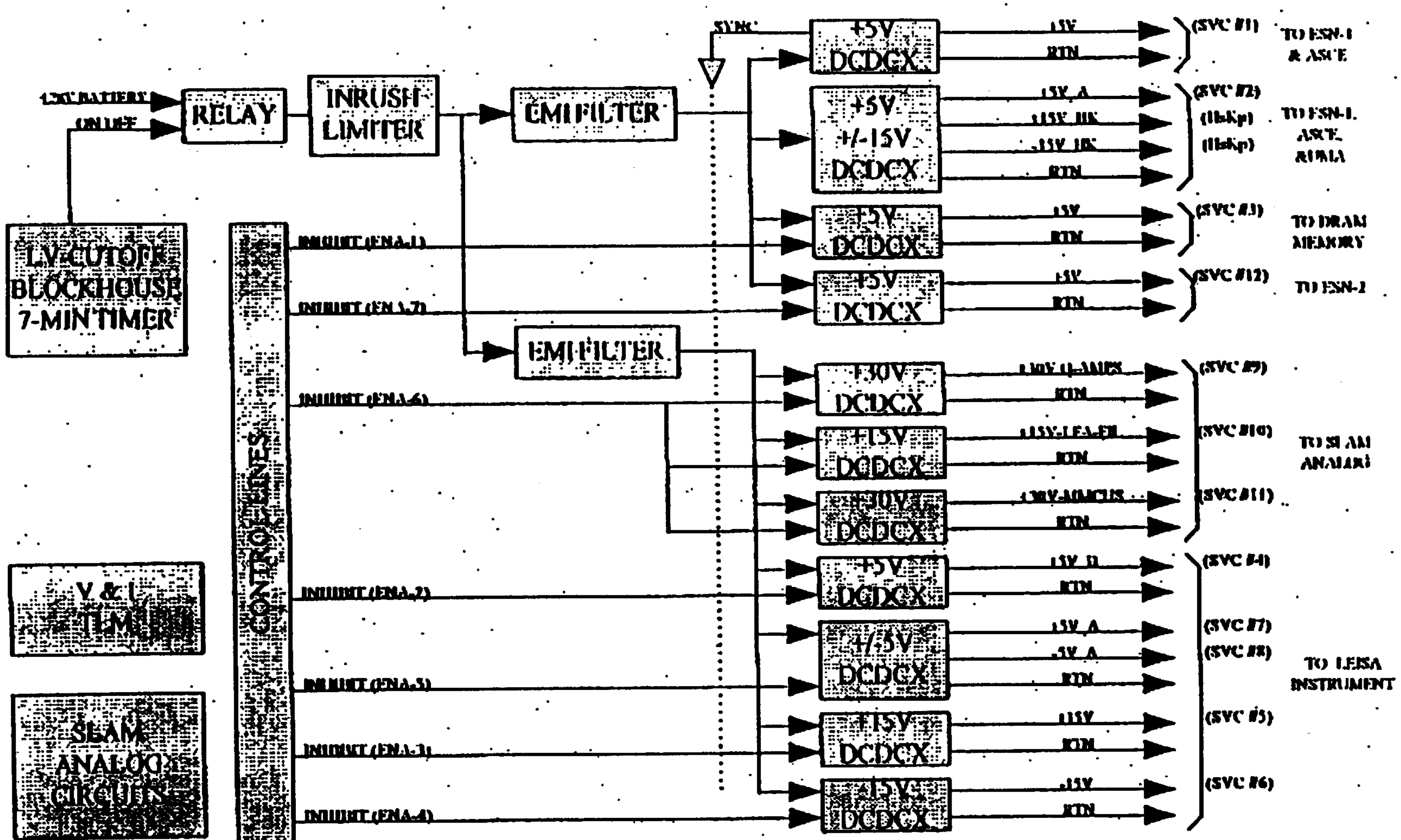




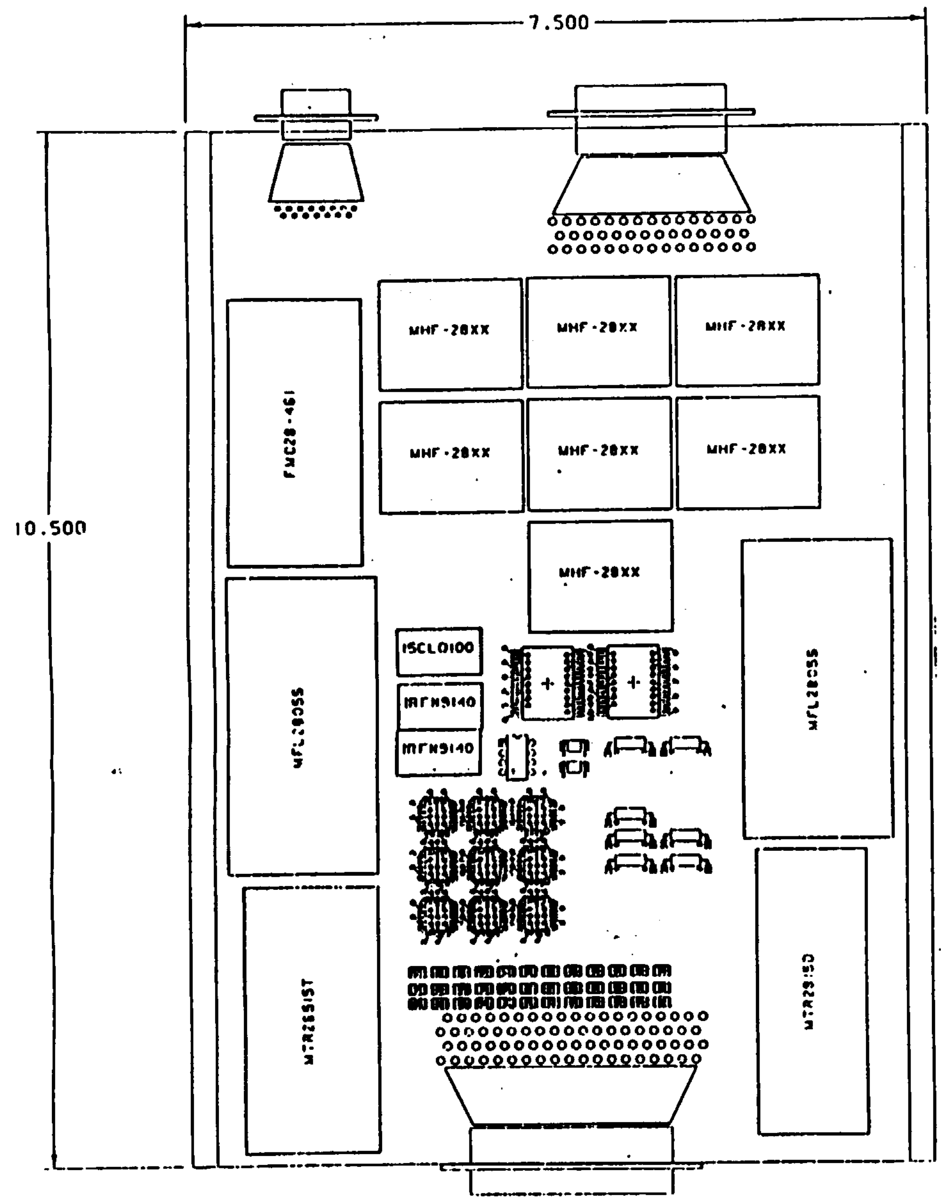
AREA STUDY FOR ESN-1
PWB SIDE "A"



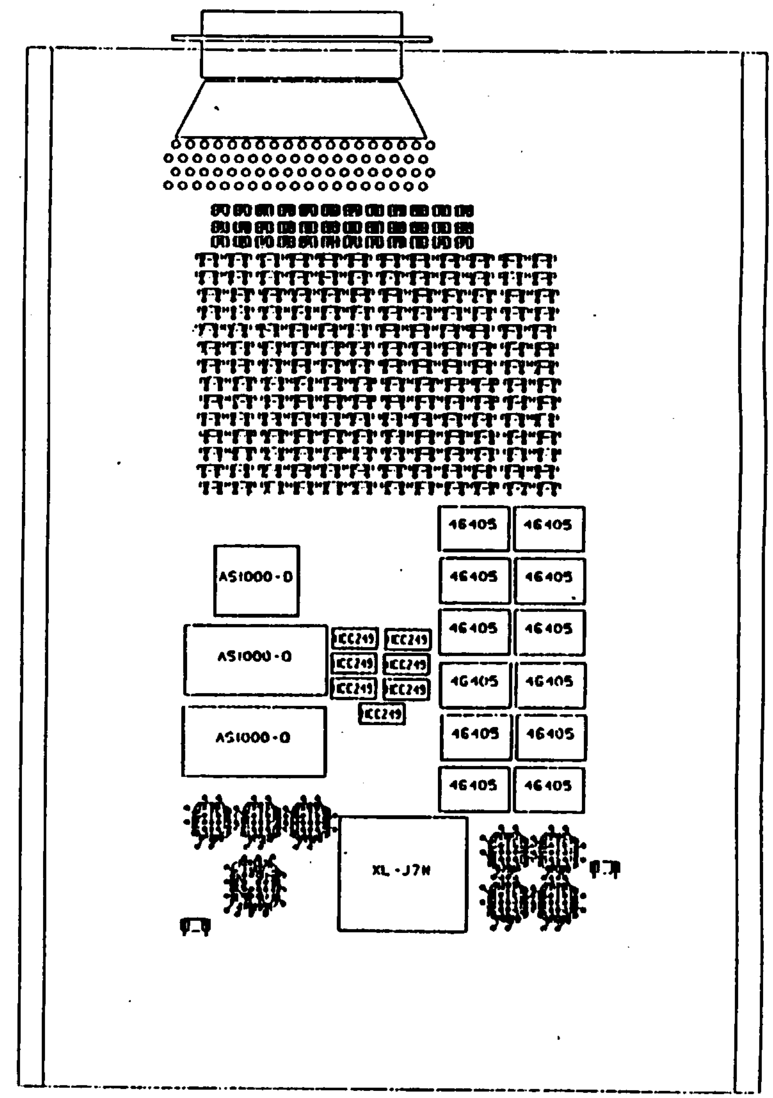
AREA STUDY FOR ESN-1
PWB SIDE "B"



Functional Block Diagram, SSTI GEM LVPC (12-16-94 Version)



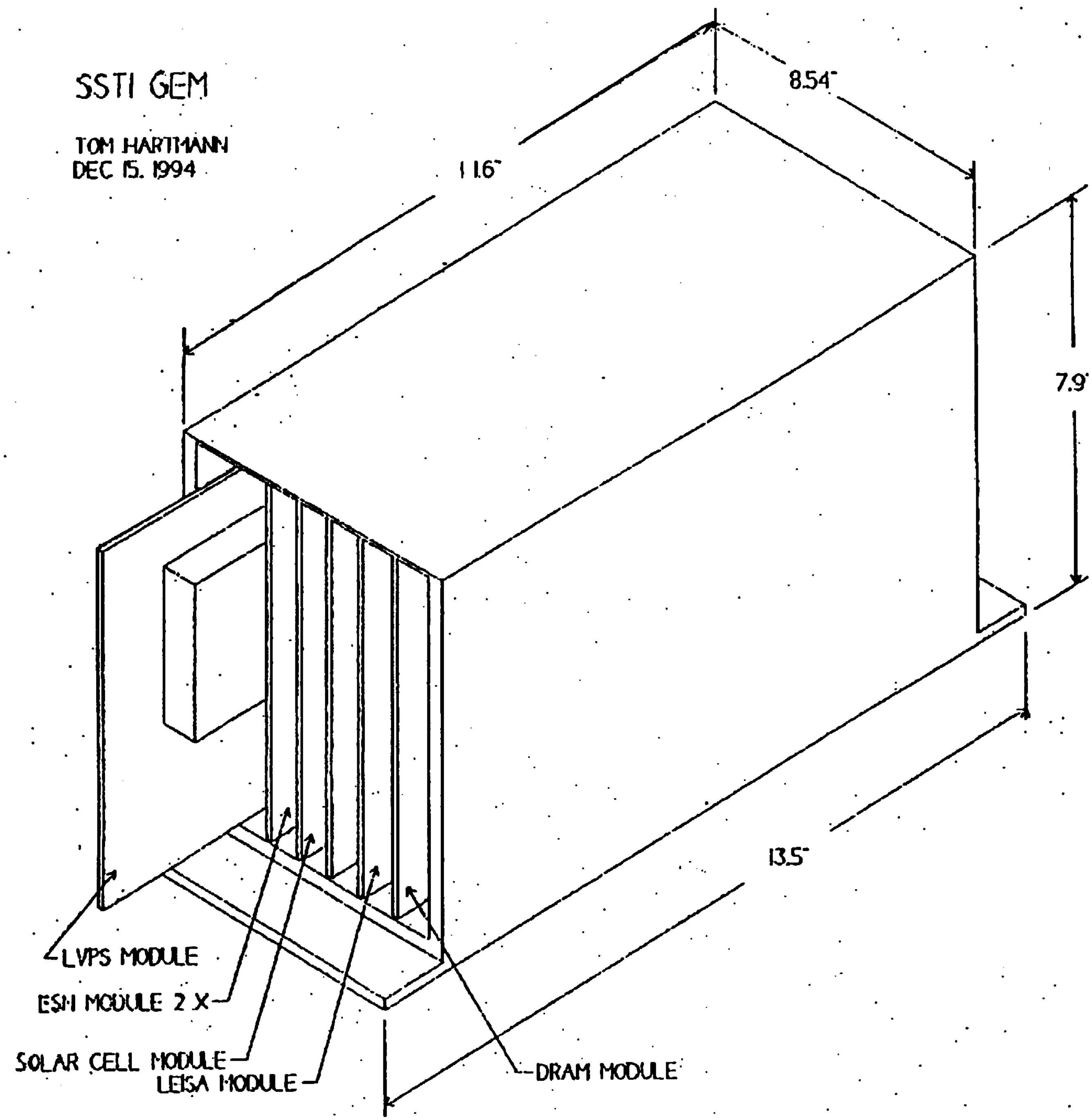
AREA STUDY FOR LVPC-1
PWB SIDE "A"



AREA STUDY FOR LVPC-1
PWB SIDE "B"

GEM Mechanical

- **Mechanical**
  - overall box dimensions 13.5" deep x 8.54" wide x 7.9" tall
  - five mounting holes on front, five on back 0.219" dia.
  - Connectors on front panel
  - Charge amps mounted on left panel, outside
  - estimated weight 22.71 pounds


SSTI GEM
TOM HARTMANN
DEC 15. 1994
11.6"
8.54"
7.9"
13.5"
LVPS MODULE
ESM MODULE 2 X
SOLAR CELL MODULE
LEISA MODULE
DRAM MODULE

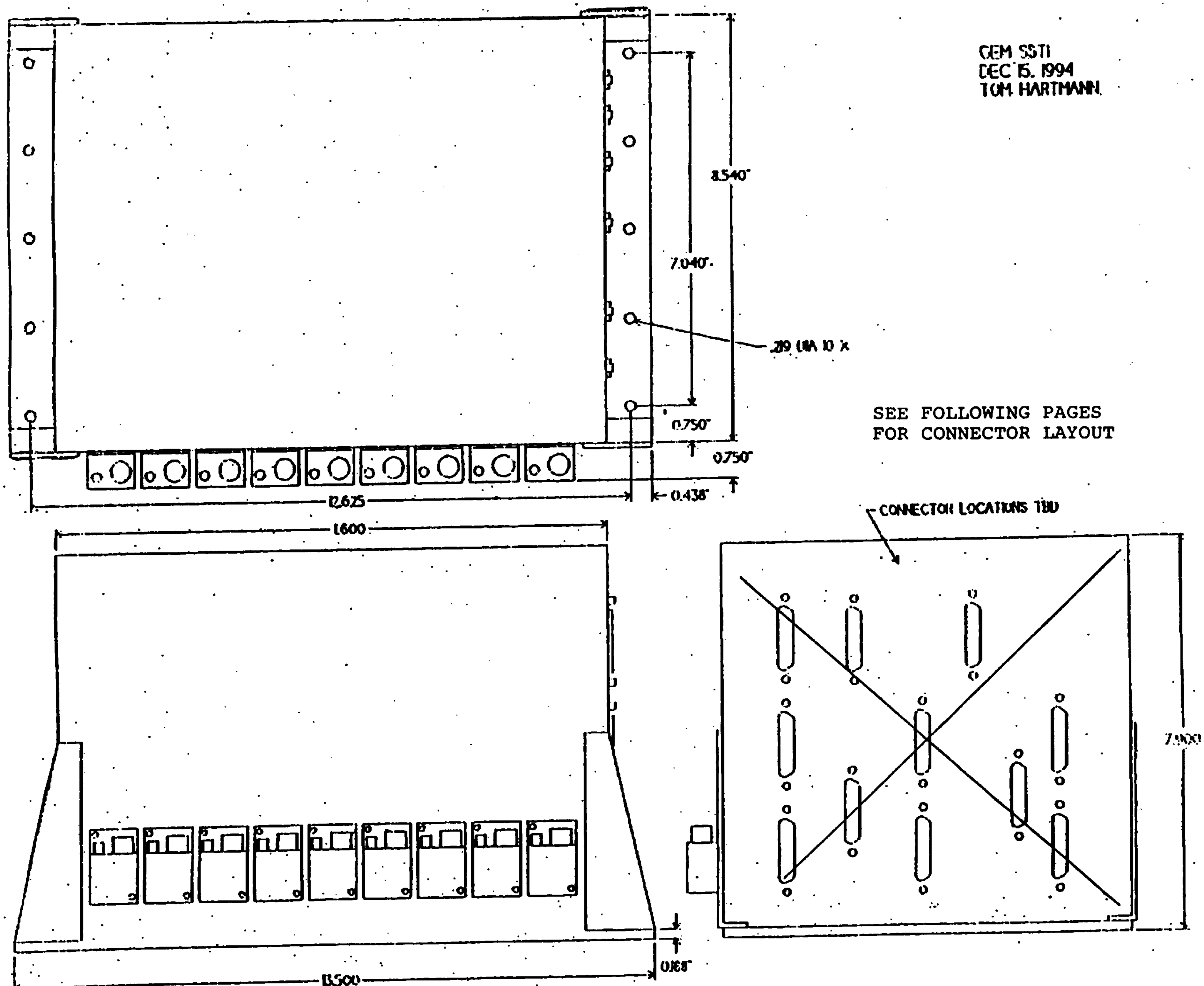
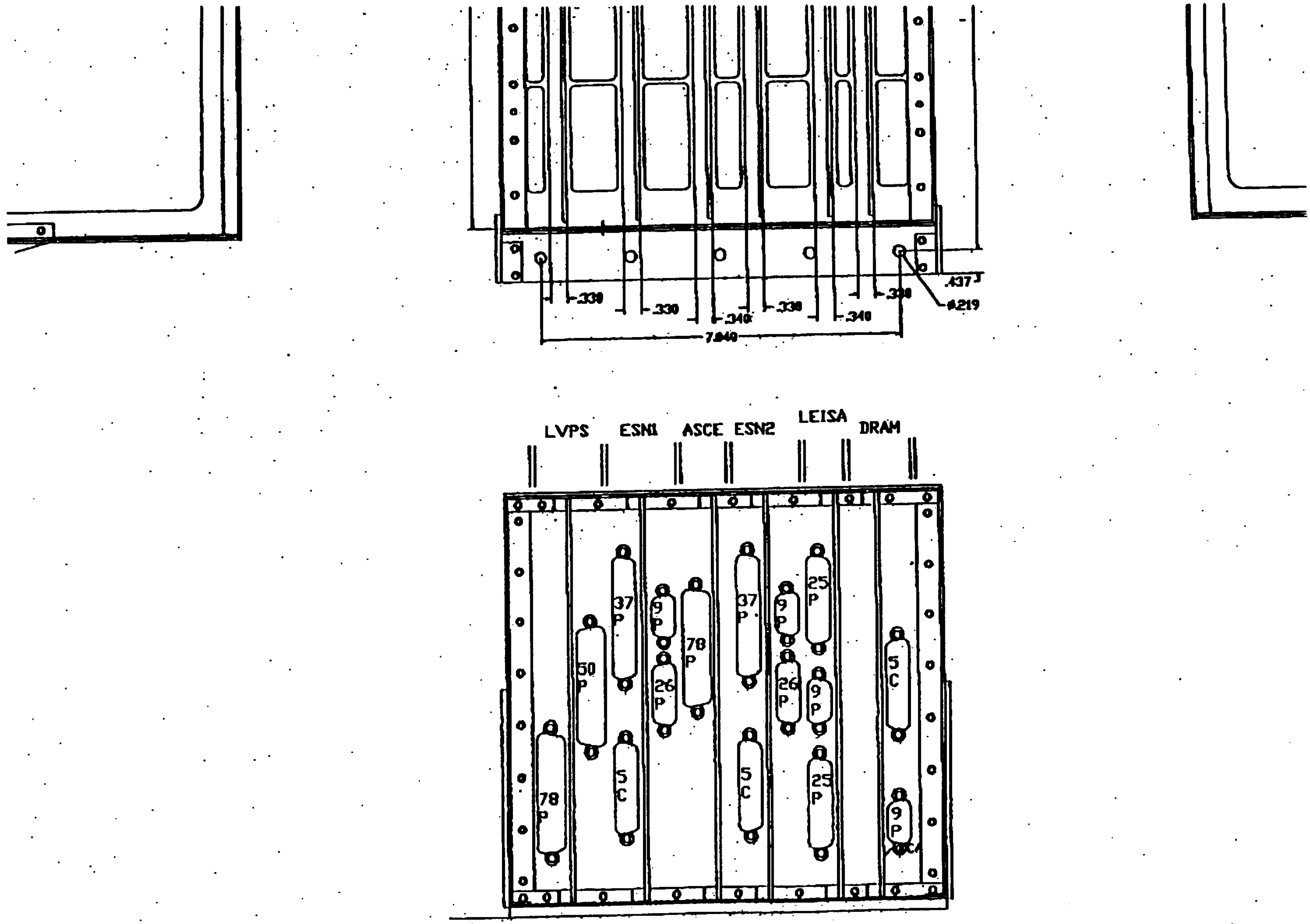

GEM SSTI
DEC 15, 1994
TOM HARTMANN
8.540"
7.040"
.219 DIA 10 X
0.750"
0.750"
0.438"
12.625
SEE FOLLOWING PAGES
FOR CONNECTOR LAYOUT
CONNECTOR LOCATIONS TBD
1.600
7.900
0.188"
13.500

figure 2


.437
ø.219
.330
.330
.340
.330
.340
.330
7.840
LVPS
ESN1
ASCE
ESN2
LEISA
DRAM
78 P
50 P
37 P
5 C
9 P
26 P
78 P
37 P
5 C
9 P
26 P
25 P
9 P
25 P
5 C
9 P

GEM Interfaces

- Thermal
  - Anondized Aluminum Box
  - No Blankets, Radiators, Heaters etc.
  - Some power going out to LEISA camera head
  - Some power coming in from Solar Panels (ASCE)
  - Power profile depends a great deal on mode

GEM Interfaces

- **Thermal - Power Consumption**

		GEM Power Consumption 1/9/95				
MODE ->	GPS-1 or ASCE (watts)	MMCHS (watts)	SLAM (watts)	GPS-2 (watts)	LEISA (watts)	DRAM diagnostic (watts)
ESN-1/ASCE/UMA	12.5	12.5	12.5	~~12.5~~	12.5	22
DRAM			20			20
LEISA Elec					11	
Analog			5			
SLAM charge amps			1			
MMCHS Heaters		2				
ESN-2				5		
LVPC (80%)	2.5	2.9	7.7	1 ~~3.5~~	4.7	8.4
Total	**15**	**17.4**	**46.2**	6 ~~21~~	**28.2**	**50.4**
NOTE:	Assumes Lewis Spacecraft providing power to both GPS receivers					
	Assumes 80% efficient converters					
	ESN-1 = 7 Watts, ASCE = 4 Watts, uMA = 1.5 Watts					

GEM I&T Plan

- Card level functional testing of LVPC/Analog, ESN, DRAM
- Incremental box assembly and functional testing
- Accept ASCE electronics, functional testing
- Accept LEISA electronics, functional testing
- Random Vibration
- EMI/EMC
- Thermal Cycling
- Delivery

GEM Deliverables

- 1 GEM Flight unit
- SLAM transducers and charge amps
- SLAM harness
- MMCHS harness
- Software listing for GEM Flight unit
- Spacecraft to GEM ICD
- Test results (As Run Procedures)

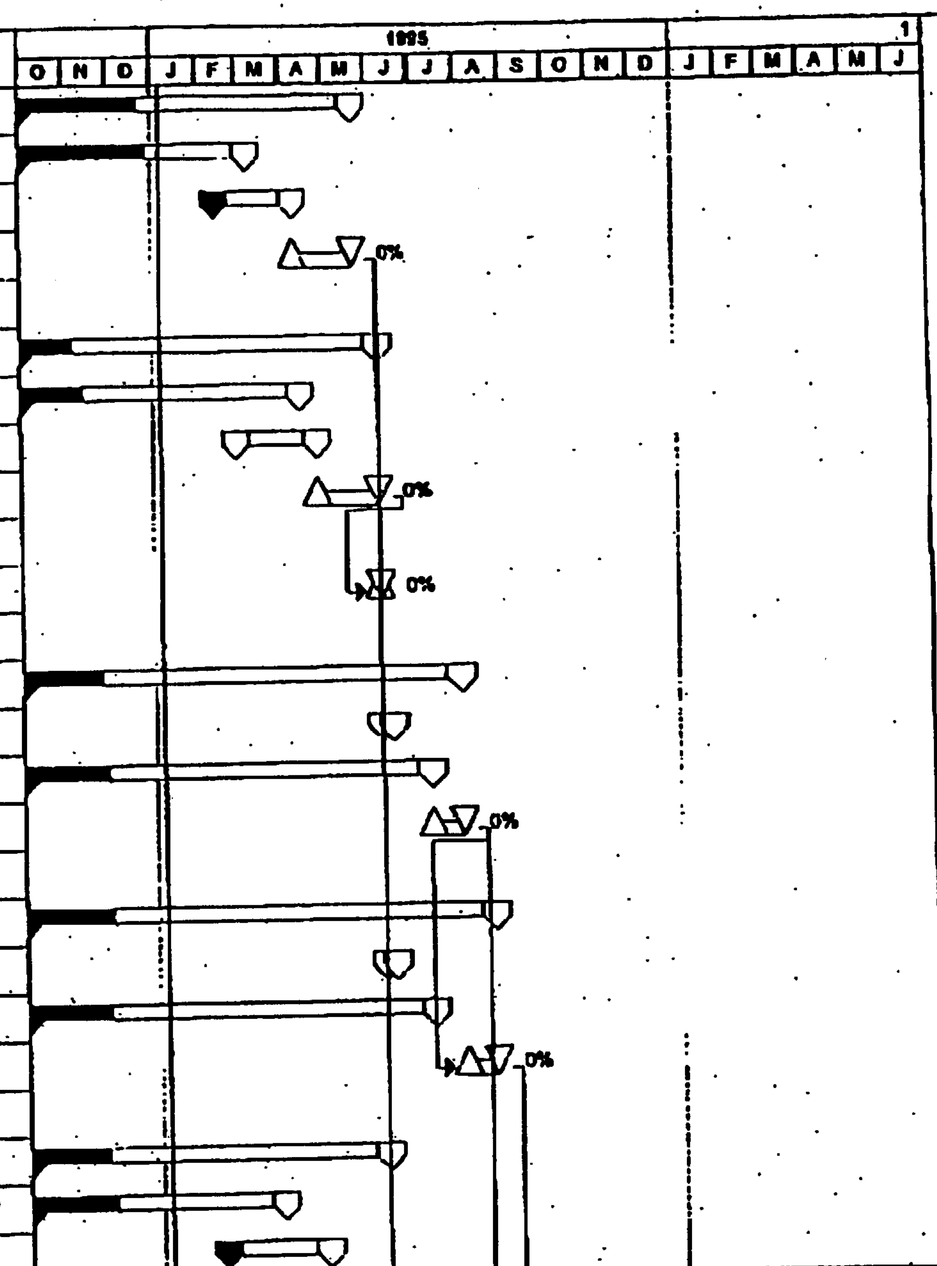
Post Delivery Support

- 2 government people at spacecraft I&T for GEM box integration for two weeks

GEM Schedule

- ESN design and fab is the critical path
  - board is necessary for testing of all the instruments
  - electrical design is complete, currently in layout

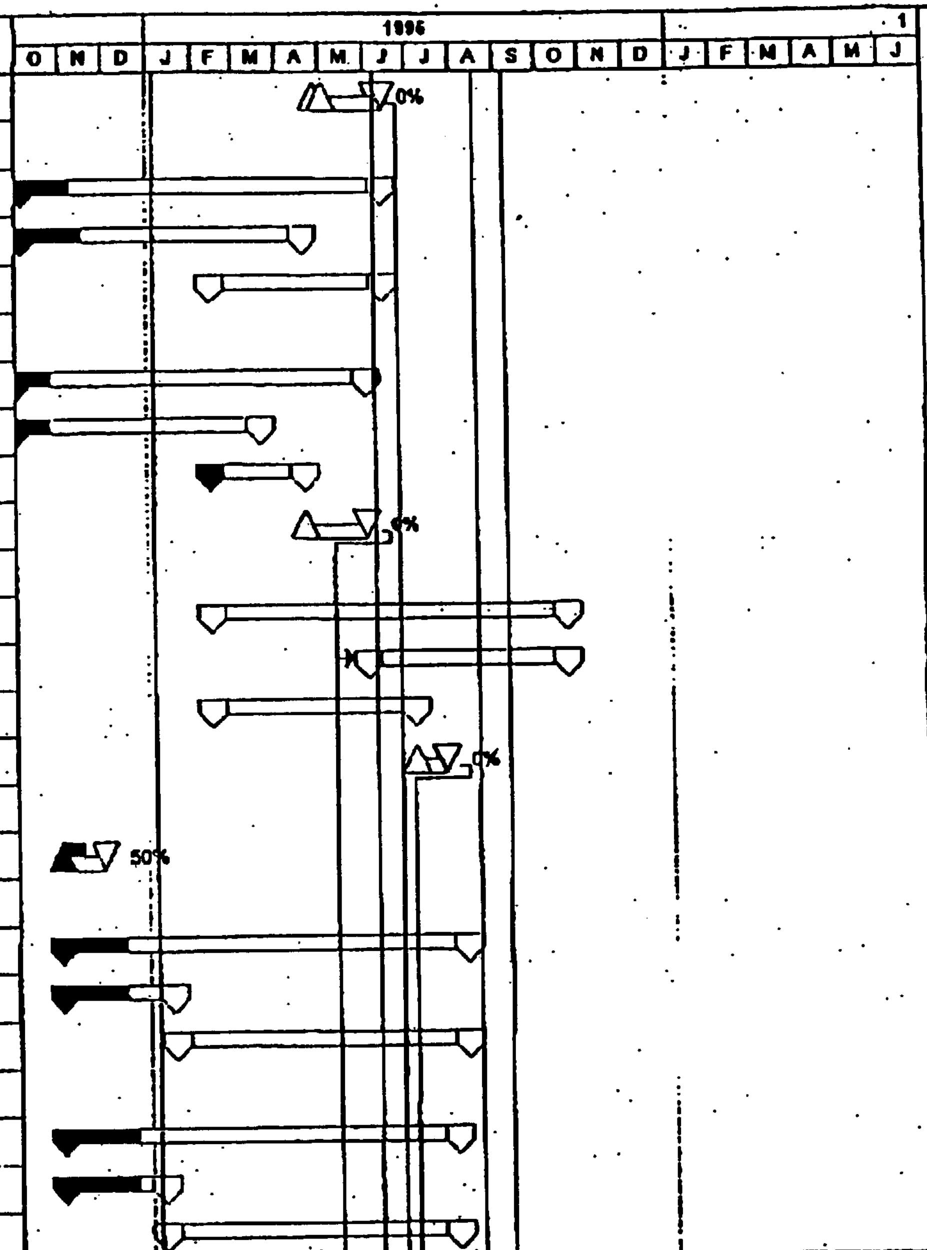
ID	Task Name	Dur	Start	Finish	% Co
1	ESN DISCRETE ETU CCA	166d	10/3/94	5/22/95	35%
2	Design	113d	10/3/94	3/8/95	56%
5	Fab/Assy	40d	2/14/95	4/10/95	7%
12	Testing	30d	4/11/95	5/22/95	0%
13					
14	ESN ASIC ETU CCA	178d	10/3/94	6/7/95	14%
15	Design	140d	10/3/94	4/14/95	22%
25	Fab/Assy	42d	2/28/95	4/28/95	0%
29	Testing	30d	4/27/95	6/7/95	0%
30					
31	ESN ASIC/DISCRETE DECISION	1d	6/8/95	6/8/95	0%
32					
33	ESN FLIGHT 1 CCA	217d	10/3/94	8/1/95	18%
34	Design	5d	6/9/95	6/15/95	0%
36	Fab/Assy	202d	10/3/94	7/11/95	20%
42	Testing	15d	7/12/95	8/1/95	0%
43					
44	ESN FLIGHT 2 CCA	232d	10/3/94	8/22/95	16%
46	Design	5d	6/9/95	6/15/95	0%
47	Fab/Assy	202d	10/3/94	7/11/95	20%
53	Testing	15d	8/2/95	8/22/95	0%
54					
55	MEMORY ETU CCA	179d	10/3/94	6/8/95	22%
56	Design	126d	10/3/94	3/27/95	34%
67	Fab/Assy	53d	2/14/95	4/27/95	7%



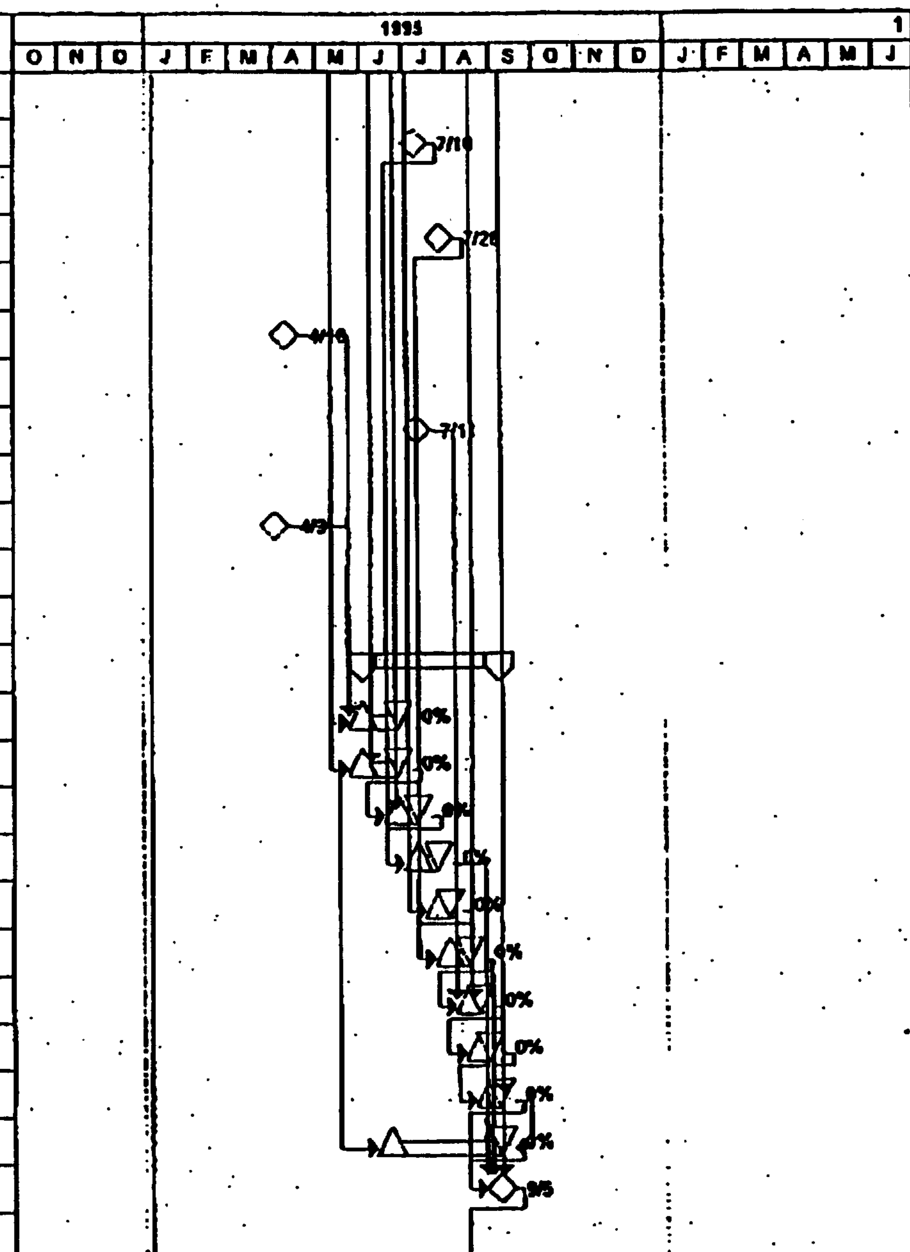
Revision 6.2

Date: 1/6/95 5:09 PM

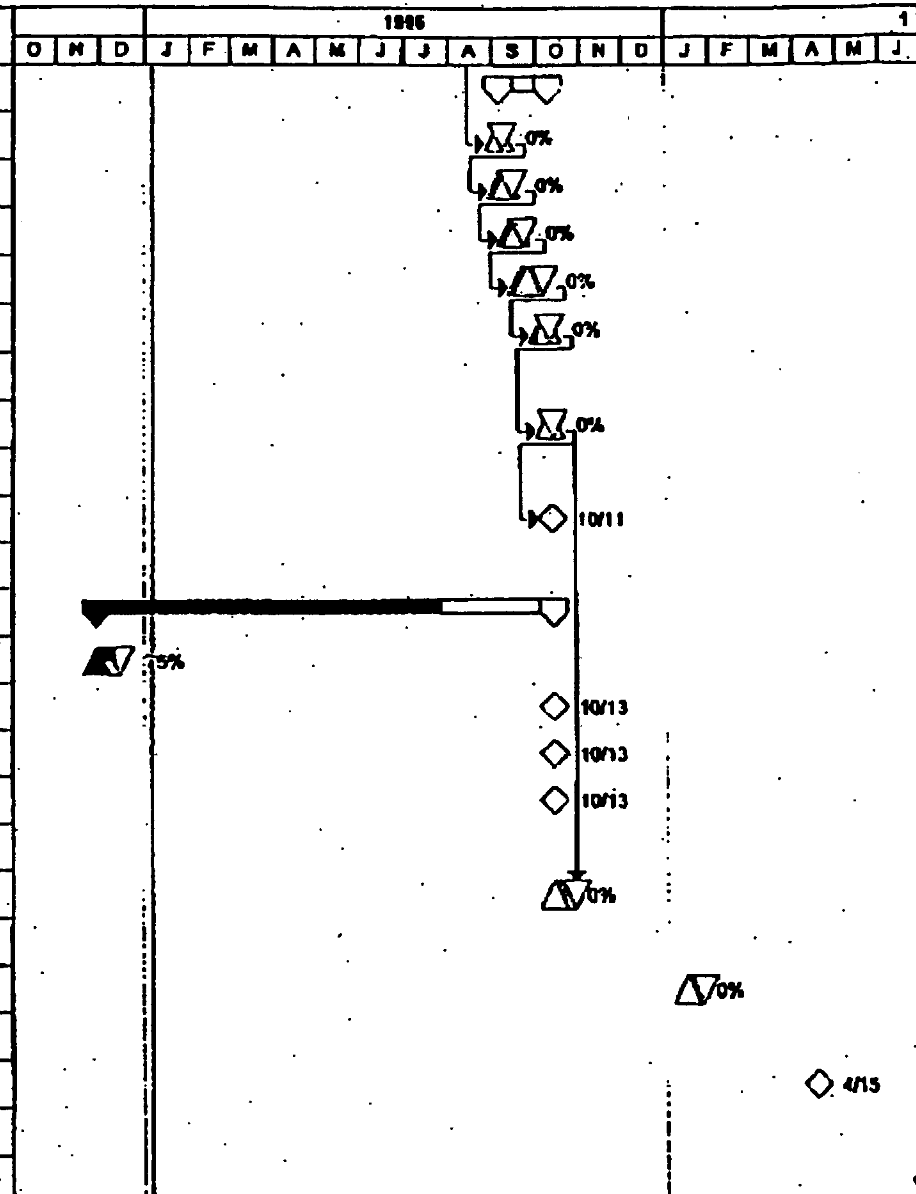
ID.	Task Name	Dur	Start	Finish	% Co
71	Testing	30d	4/28/95	6/8/95	0%
72					
73	MEMORY FLIGHT CCA	179d	10/6/94	6/13/95	13%
74	Design	140d	10/6/94	4/20/95	21%
82	Fab/Assy	86d	2/14/95	6/13/95	0%
88					
89	LVPC / ANALOG ETU CCA	174d	10/3/94	6/1/95	10%
90	Design	121d	10/3/94	3/20/95	13%
97	Fab/Assy	48d	2/14/95	4/20/95	7%
101	Testing	30d	4/21/95	6/1/95	0%
102					
103	LVPC/ANALOG FLIGHT CCA	179d	2/14/95	10/19/95	0%
104	Design	100d	6/2/95	10/19/95	0%
107	Fab/Assy	101d	2/14/95	7/4/95	0%
112	Testing	15d	7/5/95	7/25/95	0%
113					
114	INTERNAL HARNESS Defined	22d	11/1/94	11/30/94	50%
115					
116	DRAM Software	201d	11/1/94	8/8/95	16%
117	Design	56d	11/1/94	1/17/95	59%
123	Test	145d	1/18/95	8/8/95	0%
128					
129	ESN Software Development	195d	11/1/94	7/31/95	19%
130	Design	50d	11/1/94	1/9/95	73%
142	Test	145d	1/10/95	7/31/95	0%



ID	Task Name	Dur	Start	Finish	% Co
147					
148	SOLAR CELL CARD Received From J	0d	7/10/95	7/10/95	0%
149					
150	LEISA CARD Received From Code 71	0d	7/28/95	7/28/95	0%
151					
152	GEM ETU Chassis Rcvd From Code 7	0d	4/10/95	4/10/95	0%
153					
154	GEM Flight Chassis Rcvd From Code	0d	7/11/95	7/11/95	0%
155					
156	INTERNAL HARNESS - ETU (Code 733	0d	4/3/95	4/3/95	0%
157					
158					
159	GEM Unit Integration & Test	68d	6/2/95	9/5/95	0%
160	LVPC CCA	17d	6/2/95	6/26/95	0%
161	ESN DISCRETE CCA	17d	6/2/95	6/26/95	0%
162	MEMORY CCA	10d	6/27/95	7/10/95	0%
163	SOLAR CELL CARD	10d	7/11/95	7/24/95	0%
164	LVPC FLIGHT CCA	5d	7/26/95	8/1/95	0%
165	LEISA CARD	10d	8/2/95	8/15/95	0%
166	ESN FLIGHT 1 CCA	5d	8/16/95	8/22/95	0%
167	MEMORY FLIGHT CCA	5d	8/23/95	8/29/95	0%
168	ESN FLIGHT 2 CCA	5d	8/30/95	9/5/95	0%
169	Software I&T	55d	6/21/95	9/5/95	0%
170	GEM Flight Unit I & T Complete	0d	9/5/95	9/5/95	0%
171					



ID	Task Name	Dur	Start	Finish	% Co
172	Qualification	24d	9/6/96	10/9/96	0%
173	Pre-Qual Functional Testing	2d	9/6/95	9/7/95	0%
174	EMI	5d	9/8/95	9/14/95	0%
175	Shock/Vibration	5d	9/15/95	9/21/95	0%
176	Thermal Vacuum	10d	9/22/95	10/5/95	0%
177	Post-Qual Functional Testing	2d	10/6/95	10/9/95	0%
178					
179	Package/Ship to TRW	2d	10/10/95	10/11/95	0%
180					
181	GEM @ TRW Ready for S/C I&T	0d	10/11/95	10/11/95	0%
182					
183	Reports/Documentation	227d	11/30/94	10/13/95	75%
184	S/C to GEM ICD	12d	11/30/94	12/15/94	75%
185	Environmental Test Report	0d	10/13/95	10/13/95	0%
186	Instrument Test Reports & Calibrati	0d	10/13/95	10/13/95	0%
187	Software Listings	0d	10/13/95	10/13/95	0%
188					
189	GEM / Spacecraft I&T	11d	10/13/95	10/27/95	0%
190					
191	Spacecraft Environmental Test	10d	1/15/96	1/26/96	0%
192					
193	Final IST	0d	4/16/96	4/15/96	0%
194					
195	Launch	0d	7/1/96	7/1/96	0%



Status

- Spacecraft to GEM ICD will be signed this week
- GEM to Experiment ICDs will all be signed this week.
- Box is designed, TRW has requested further analysis into reducing chassis weight
- ESN design is complete, currently in layout
- DRAM design complete, entering layout this week
- LVPC recently modified to accept +5V for ESN-2

Issues/Concerns

- Redesign of box to save weight may impact schedule
- EV2-099 Thermal Cycling temperature ranges are extreme
- SLAM start signal must be resolved

PAYLOADS & TECHNOLOGY DEMONSTRATIONS

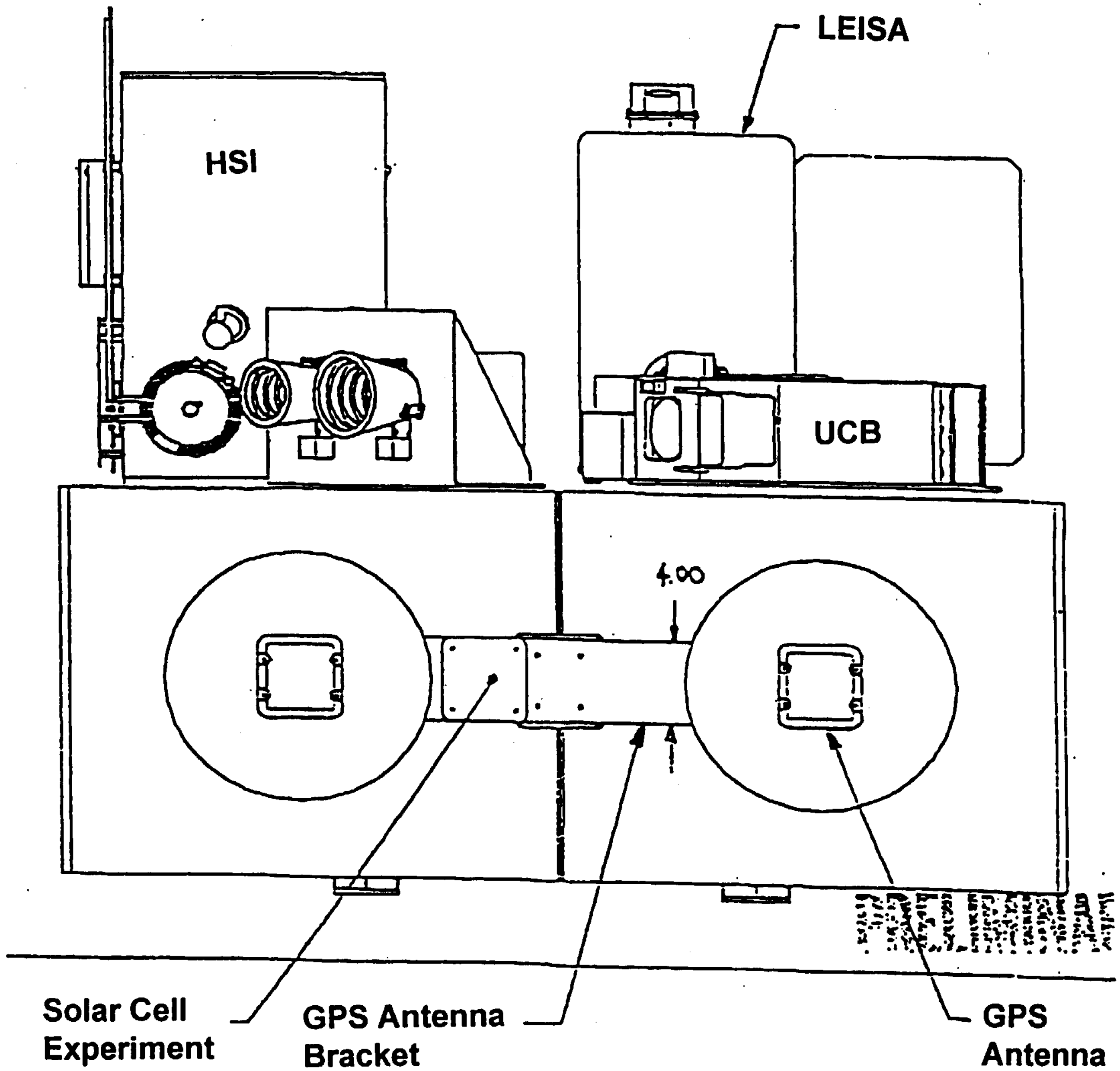
Multi-junction GaAs Solar Cells

L. Slifer

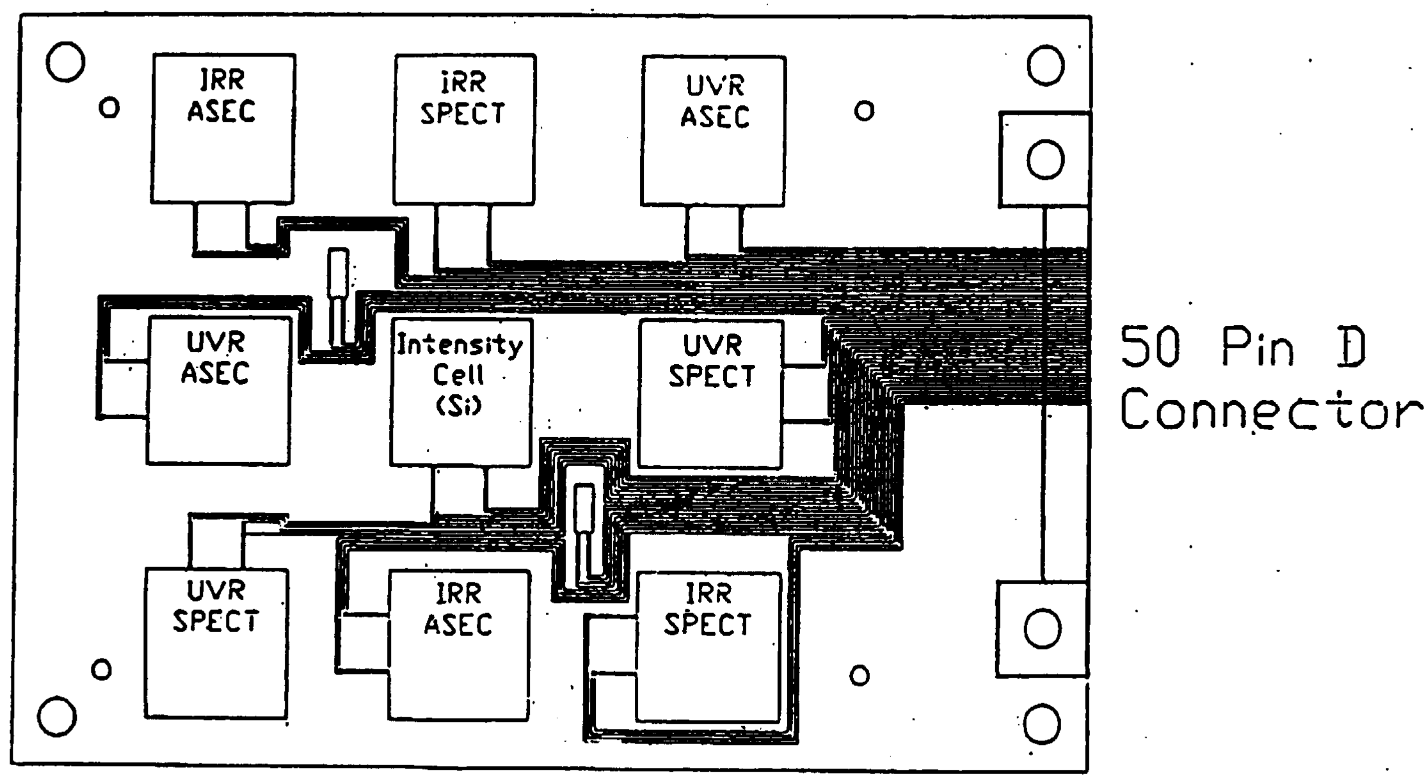
DESCRIPTION

CASCADE SOLAR CELLS	**DR. E. GADDY (GSFC)**
AMORPHOUS SOLAR CELLS	G. VENDURA (TRW)
SOLAR CELL ELECTRONICS	TRW CONTRACT WITH J&T

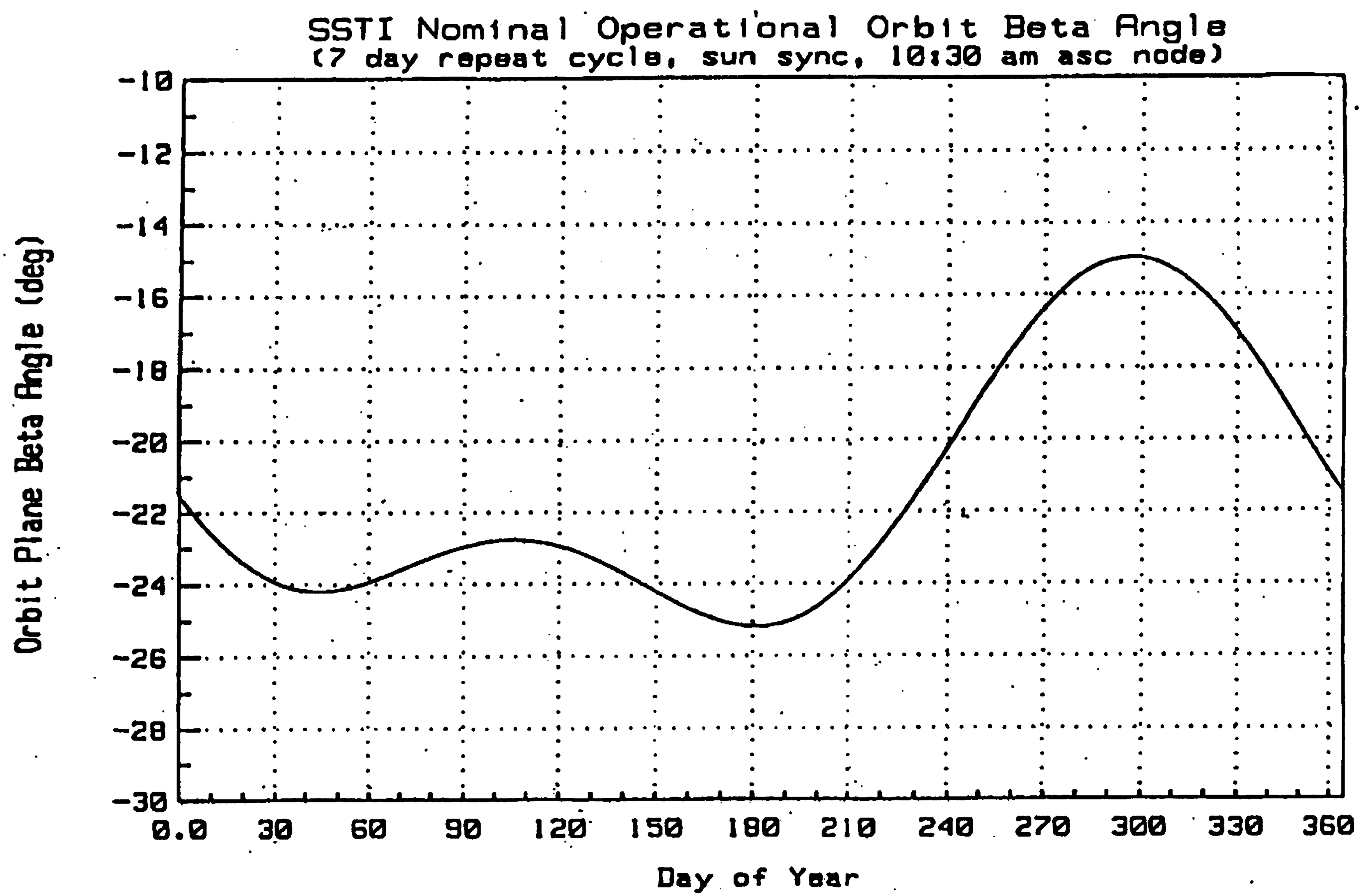
<u>MOUNTING ON SPACECRAFT</u>



PRELIMINARY SOLAR CELL LAYOUT
(Example)



BETA ANGLE



SSTI Nominal Operational Orbit Beta Angle
(7 day repeat cycle, sun sync, 10:30 am asc node)
Orbit Plane Beta Angle (deg)
-10
-12
-14
-16
-18
-20
-22
-24
-26
-28
-30
0.0
30
60
90
120
150
180
210
240
270
300
330
360
Day of Year

PERFORMANCE

SHORT CIRCUIT CURRENT	I_{sc}=60.0 ma
MAX. POWER CURRENT	I_{mp}=58.0 ma
OPEN CIRCUIT VOLTAGE	V_{oc}=2.00 volts
MAX. POWER (28°C)	P_{mp}=116 mw
EFFICIENCY	Eff.=21.5 %
TEMP. COEFF. of Voc	β=-4.4 mv/°C
TEMP. COEFF. of Pmp	Coeff.= 0.22%/°C

Degradations expected to be similar to GaAs/Ge

STATUS

DESIGN (ICD REVIEWED/UNDER REVISION)

FIRM: LOCATION
COMPONENTS
SUBSTRATE
CELLS/COVERS
CELL LAYOUT

TBD: DETAILS (WIRE SIZE AND ROUTING, INSULATOR, ADHESIVES)

PROCUREMENT

CELL ASSEMBLIES--PRs SUBMITTED

TEST APPROACH AND PLANS

CELL ASSEMBLY TESTING

MECHANICAL TESTING (VISUAL INSP., SIZE, WEIGHT)
PERFORMANCE AT 28°C
PERFORMANCE AT ELEVATED TEMPERATURE (<90°C)
HUMIDITY TEST (ACCELERATED)
REVERSE BIAS TEST

COMPLETED "BILLBOARD"

VIBRATION AND THERMAL (ON SPACECRAFT)

PAYLOADS & TECHNOLOGY DEMONSTRATIONS

Amorphous Silicon Solar Cells

B. Starritt

Experiment Configuration

- 3 Large α-Si:H cell modules ($\approx$28 cells/module)
  - 1 will experience shadowing and will incorporate diode bypass
  - 1 will be mounted directly to the substrate
  - 1 will be thermally isolated from the substrate on a semirigid mount
- 3 Small α-Si:H cell modules (TBD cells/module)
  - 2 will be mounted directly to the substrate
  - 1 will be thermally isolated from the substrate on a semirigid mount

SSTI

Amorphous Si Cell Status

TRW

- Presently working with Solarex to develop large-area (12"x13") α-Si:H cell modules on thin superstrates (4 to 8 mil glass)
  - Manufacturing process needs to be adapted from thick glass superstrate line
- Defining cell configuration (string length) for small (3"x3") α-Si:H cell modules
  - Will use 8-mil CMZ glass superstrates
  - Starting negotiations for procurement
- Development of module output connection soldering technique has been started

PAYLOADS & TECHNOLOGY DEMONSTRATIONS

ASCE Electronics Design

F. Larrick

Advanced Solar Cell Experiment Card

Requirements Summary

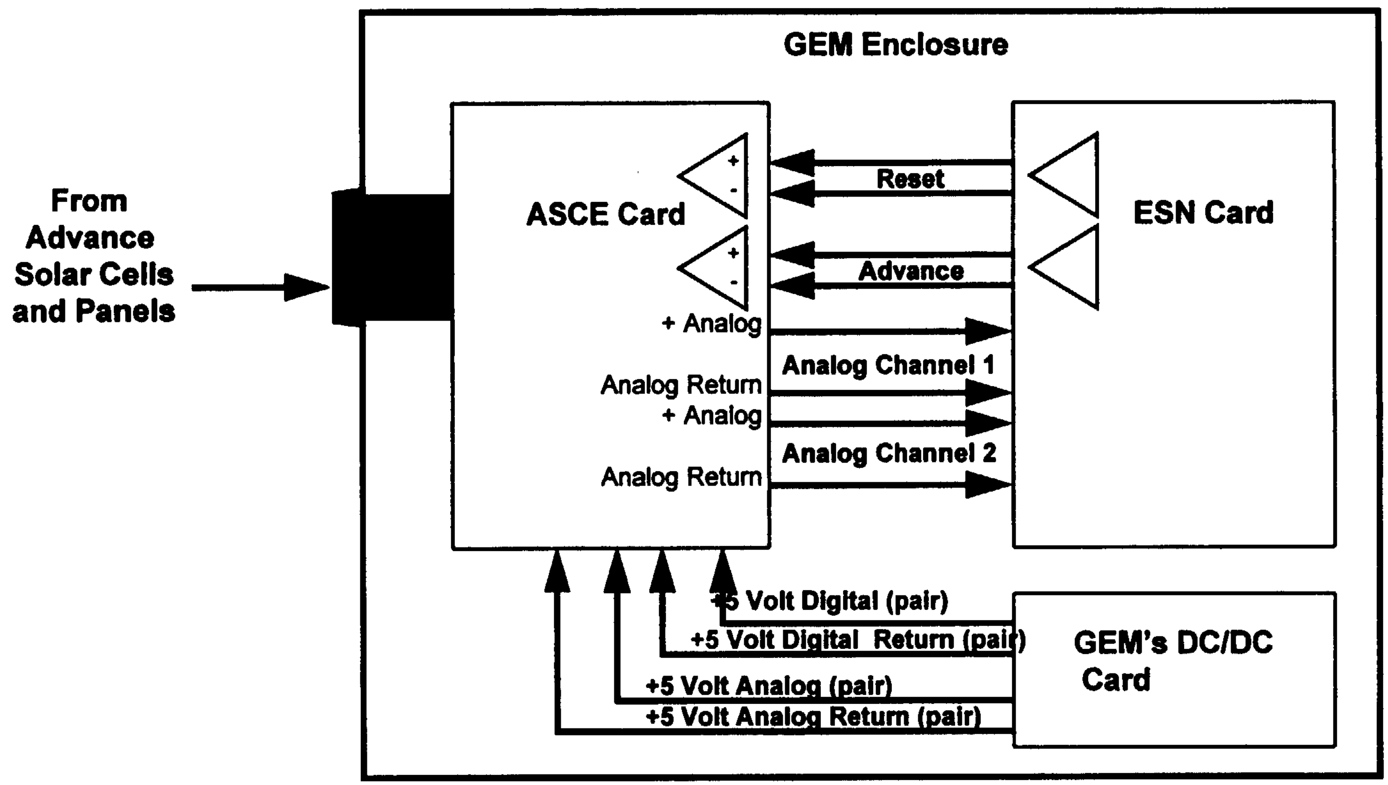
Requirements	Capabilities	Verification
Measurement of 3 Amorphous Panels	32 V Open circuit .7 Amps Short circuit	Measured
Measurement of 3 Amorphous Cells	6V Open circuit .7 Amps Short circuit	Measured
Measurement of 8 Cascade Cells	3V Open circuit .08 Amps Short circuit	Measured
Measurement of 4 pairs (8 total cells) of GaAs Cells	4V Open circuit .6 Amps Short circuit	Measured
Measurement of 1 GaAs Reference Cell	2V Open circuit .6 Amps Short circuit	Measured
Measurement of 1 Si Reference Cell	2V Open circuit .6 Amps Short circuit	Measured
Measurement of 1 Heavy shielded Si Cell	2V Open circuit .6 Amps Short circuit	Measured
Measurement of 16 AD590 Temperature devices	-95°C to +87°C with survival at -100°C to +92°C	Measured
Determine cell's I/V characteristics	Acquire 32 I/V samples, >30% of sample centered around knee	Measured & Analysis
Determine cell's temperature	Acquire temperature sample after the cells I/V samples	Inspection

Advanced Solar Cell Experiment Card

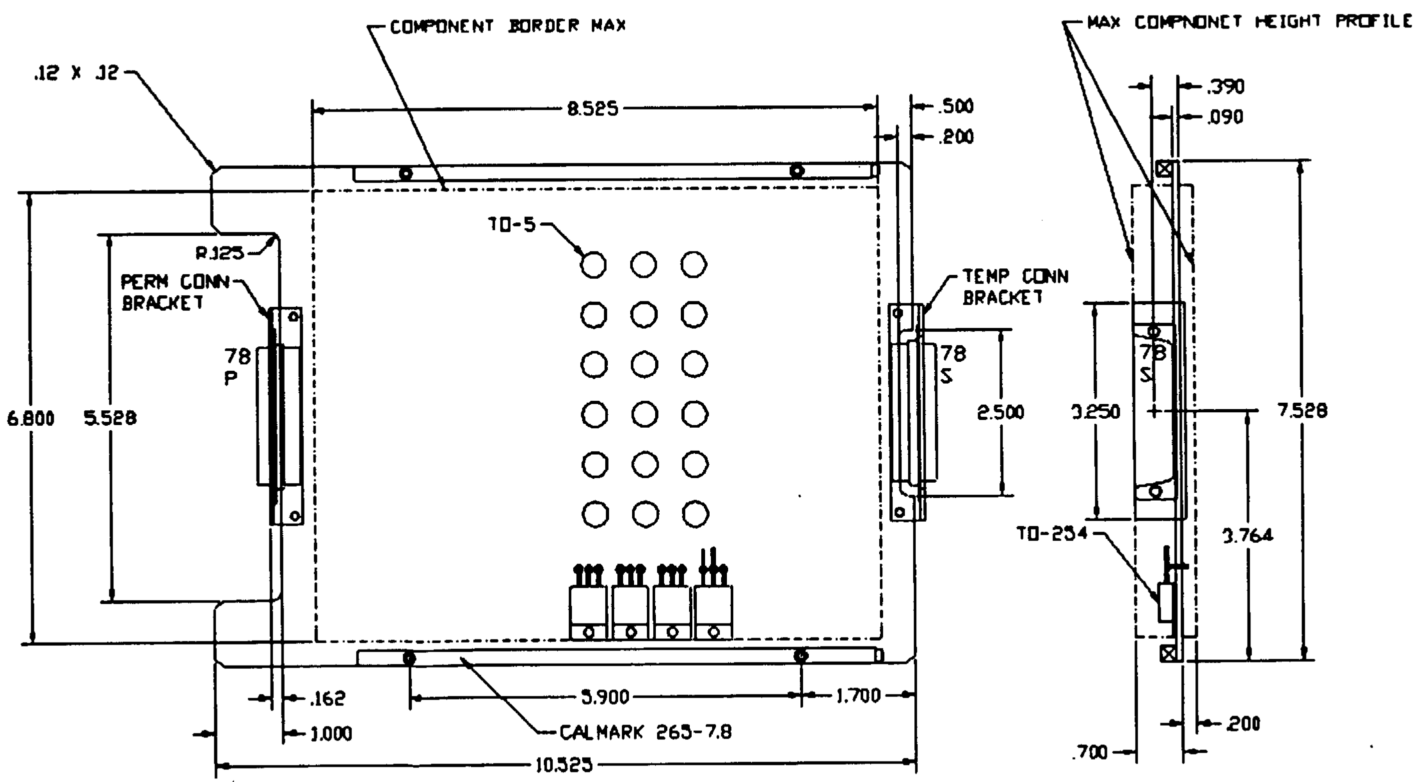
The Advanced Solar Cell will provide the following capabilities:

- Measure the I/V characteristic of up to 21 Cells
  - Cascade, GaAs, and Amorphous Si cells
- Collect Data From Up to 16 (AD590) Temperature Devices
- For Each Cell Collect 32 Voltage/Current Pairs From Open Circuit Voltage to Short Circuit current
  - More of the V/I samples will be taken near the Cell's "Knee"
- Reside within the Goddard Electronics Module (GEM),
  - GEM shall supply power to the ASCE and the 1553B interface to the Spacecraft for the ASCE
- Provide to GEM dual +5V Analog Outputs with GEM issuing "RESET" and "NEXT" Control Signals

Block Diagram of Advance Solar Cell Electronics

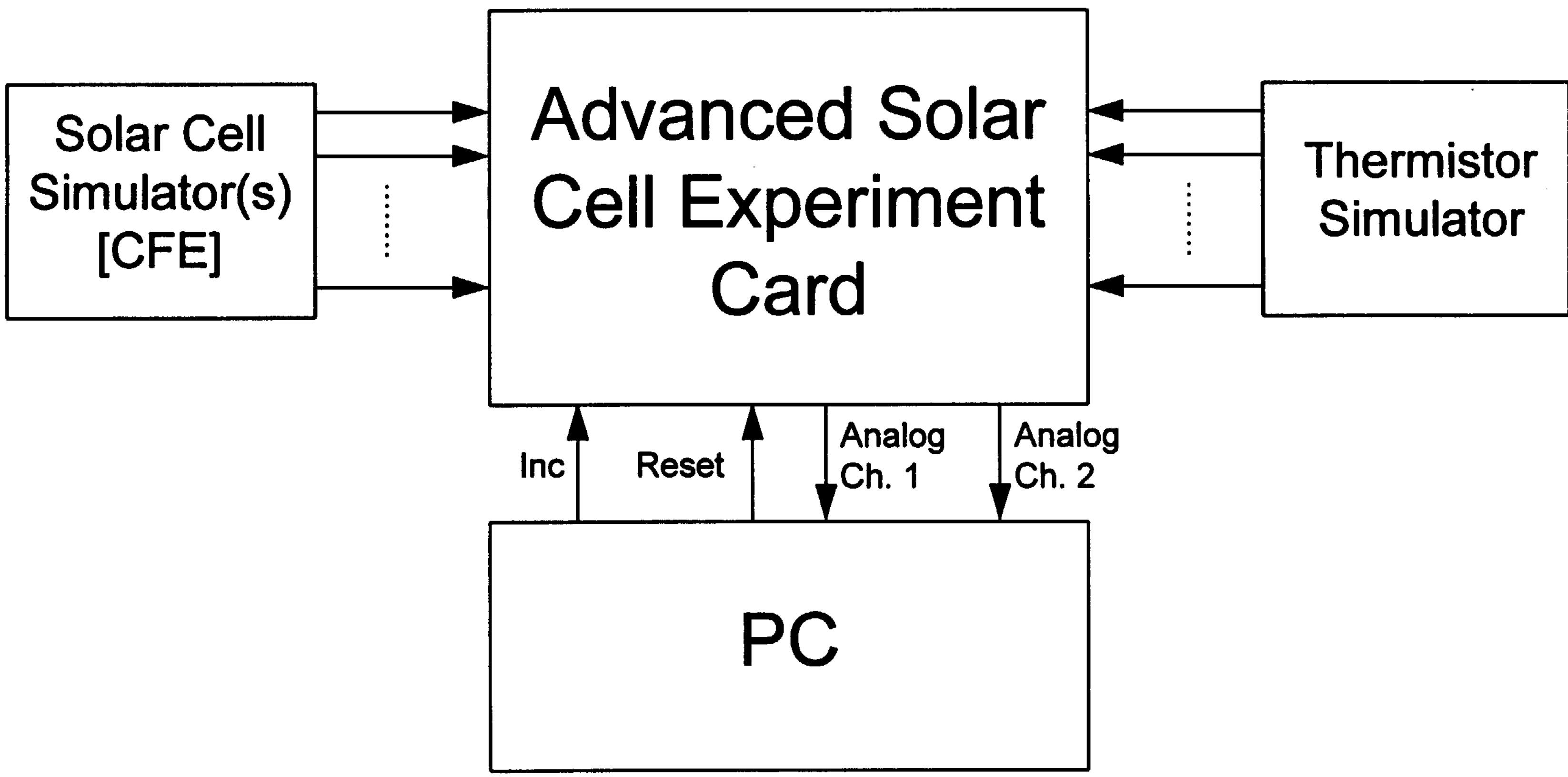


ASCE Card Preliminary Layout



ASCE Card
Acceptance Test Setup

Note: Solar Cell Simulator(s)
are to be furnished by the customer.



SSTI

PAYLOADS & TECHNOLOGY DEMONSTRATIONS

GPS Attitude Determination

F. Bauer

GPS ATTITUDE DETERMINATION FLYer (GADFLY)

SSTI LEWIS CRITICAL DESIGN AUDIT

Frank H. Bauer
Guidance & Control Branch/Code 712

January 18, 1995
NASA GSFC

1

EXPERIMENT REQUIREMENTS

- Provide on-orbit validation of GPS attitude sensing concept in Low Earth Orbit using flight qualified GPS receiver
- Provide independent calibration of GADFLY using spacecraft star tracker data
- Determine the effects and impacts of vehicle multipath

SPACECRAFT DERIVED REQUIREMENTS

- Provide Orbital State Vector information to spacecraft when GPS data available
  - 150 meters unfiltered
  - Filtered expectations–better than 30 meters (goal)
- Provide precise time reference for the Lewis spacecraft when GPS data available
  - 1 pulse-per-second discrete
  - Pulse accuracy <1 msec
- TRW will ensure that backup time and state vector capabilities exist if GPS fails or data dropouts occur

EXPERIMENT RATIONALE

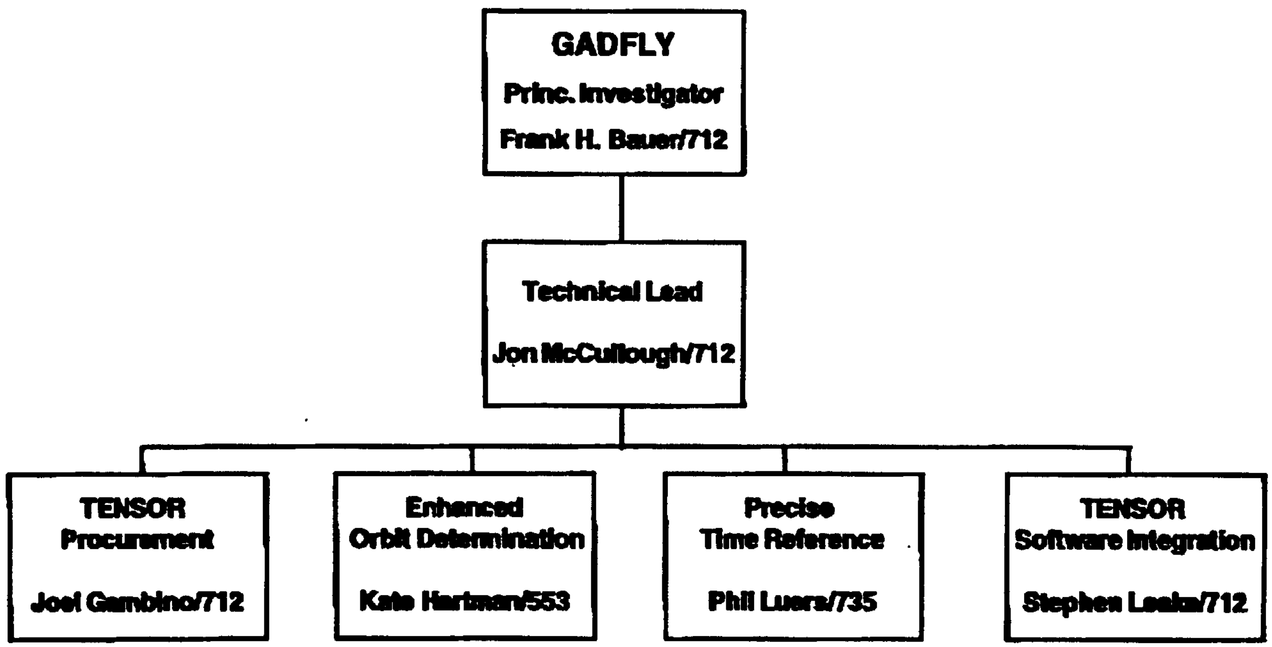
- First long duration flight of Space Qualified Attitude, Orbit and Precise Time GPS receiver
  - Space Systems/Loral (SS/L) Tensor

- Provides long duration, high accuracy calibration of GPS attitude determination performance in space

- First demonstration of GPS as a precise spacecraft time reference

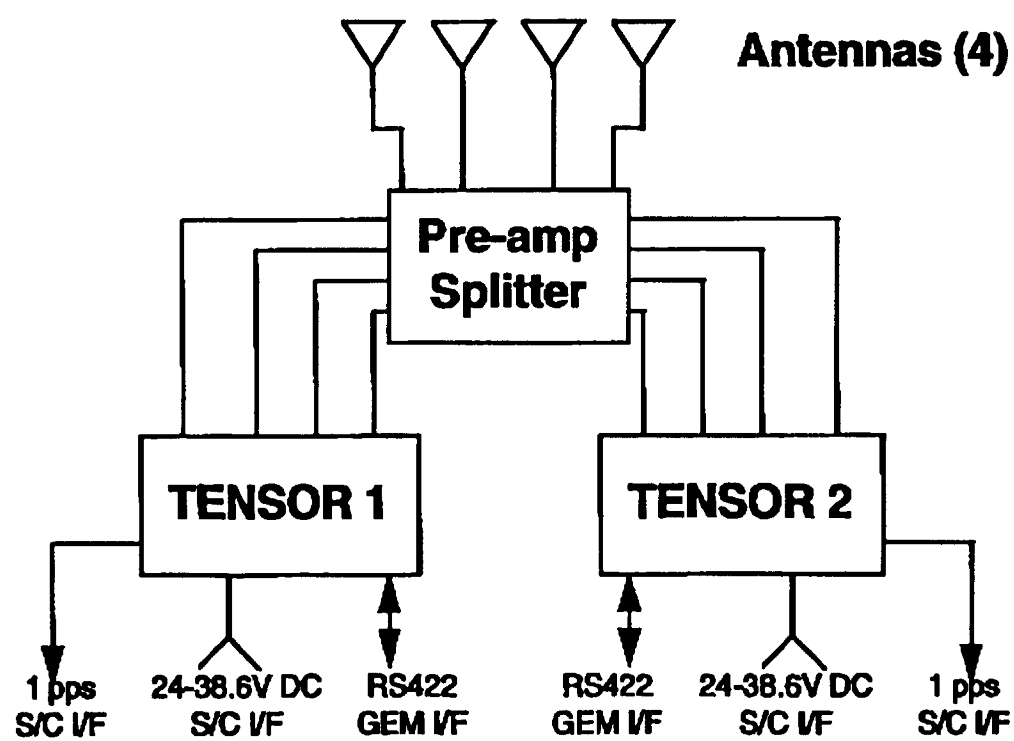
- Enhanced orbit determination algorithms promise to satisfy over 95% of LEO spacecraft missions

GADFLY MANAGEMENT STRUCTURE



5

GADFLY HARDWARE BLOCK DIAGRAM



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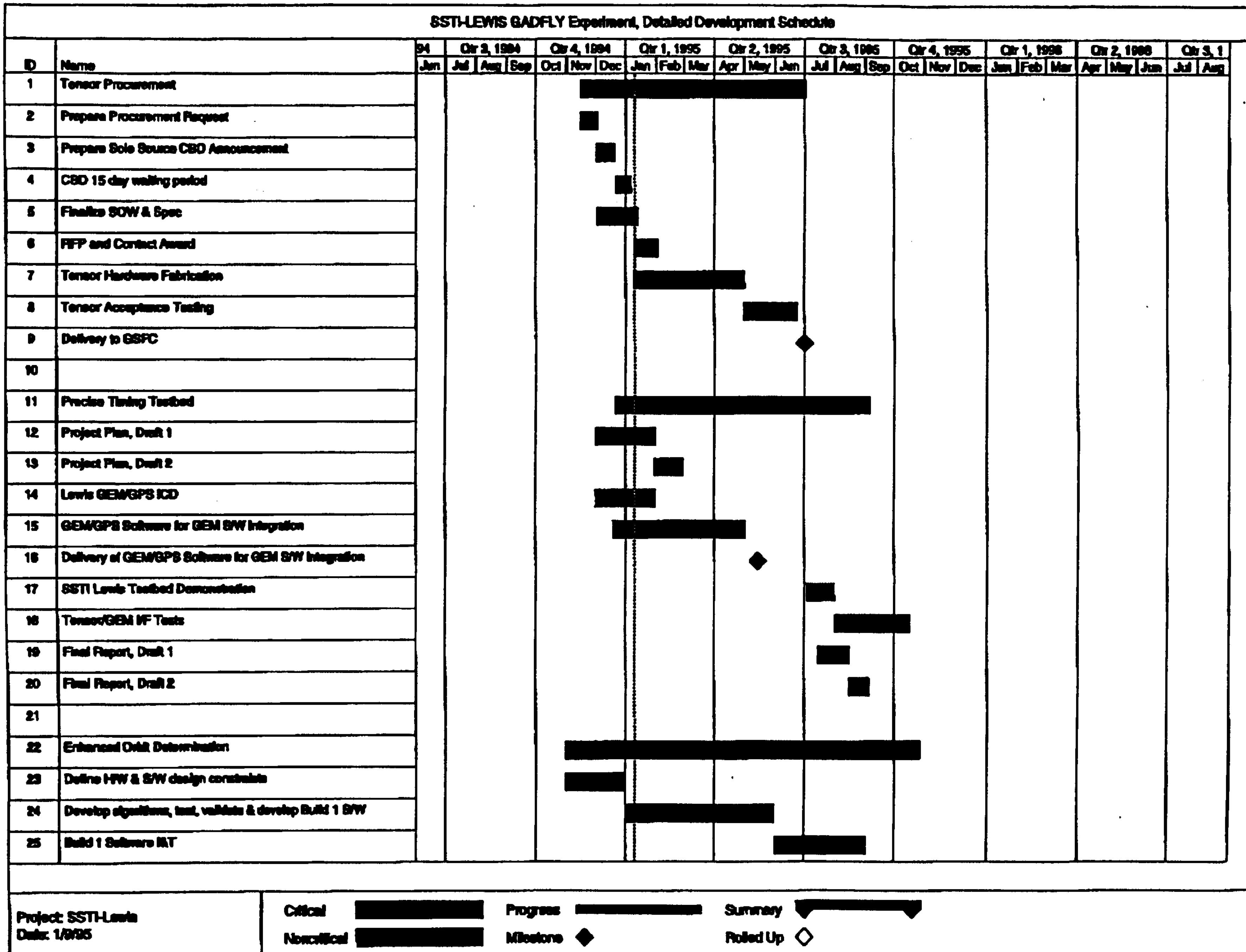
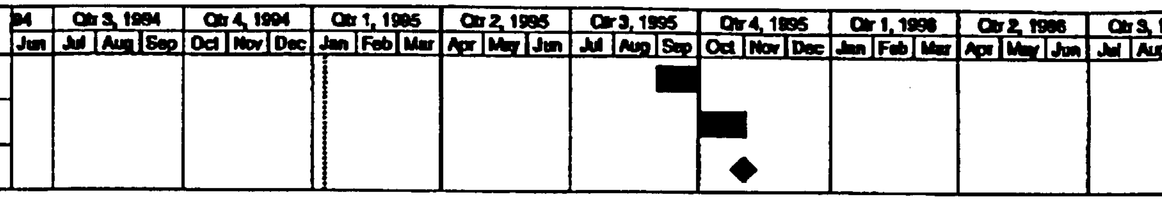

SSTI-LEWIS GADFLY Experiment, Detailed Development Schedule
ID
Name
94
Qtr 3, 1994
Qtr 4, 1994
Qtr 1, 1995
Qtr 2, 1995
Qtr 3, 1995
Qtr 4, 1995
Qtr 1, 1996
Qtr 2, 1996
Qtr 3, 1
Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug
1 Tensor Procurement
2 Prepare Procurement Request
3 Prepare Sole Source CBD Announcement
4 CBD 15 day waiting period
5 Finalize SOW & Spec
6 RFP and Contact Award
7 Tensor Hardware Fabrication
8 Tensor Acceptance Testing
9 Delivery to GSFC
10
11 Precise Timing Testbed
12 Project Plan, Draft 1
13 Project Plan, Draft 2
14 Lewis GEM/GPS ICD
15 GEM/GPS Software for GEM S/W Integration
16 Delivery of GEM/GPS Software for GEM S/W Integration
17 SSTI Lewis Testbed Demonstration
18 Tensor/GEM I/F Tests
19 Final Report, Draft 1
20 Final Report, Draft 2
21
22 Enhanced Orbit Determination
23 Define H/W & S/W design constraints
24 Develop algorithms, test, validate & develop Build 1 S/W
25 Build 1 Software I&T
Project: SSTI-Lewis
Date: 1/9/95
Critical
Noncritical
Progress
Milestone
Summary
Rolled Up
Page 1

SSTI-LEWIS GADFLY Experiment, Detailed Development Schedule

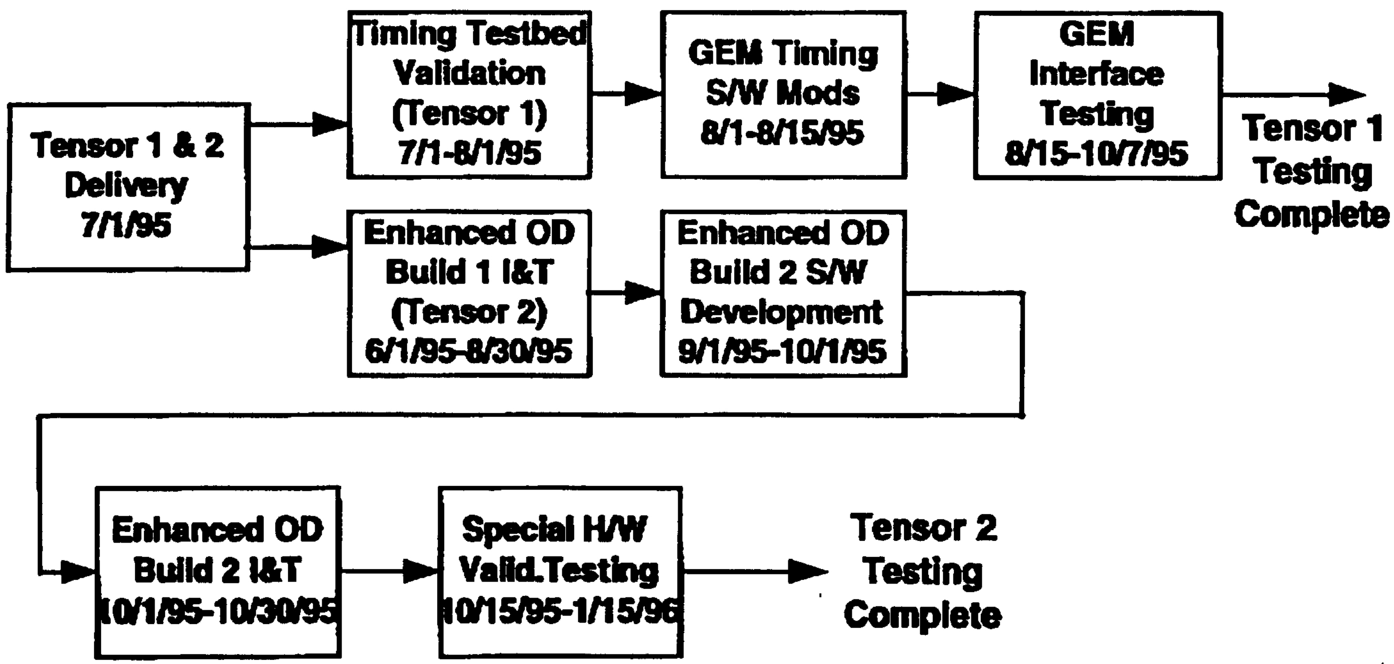
ID	Name
26	Build 2 Software Development
27	Build 2 Software I&T
28	Build 2 Software Integration Complete



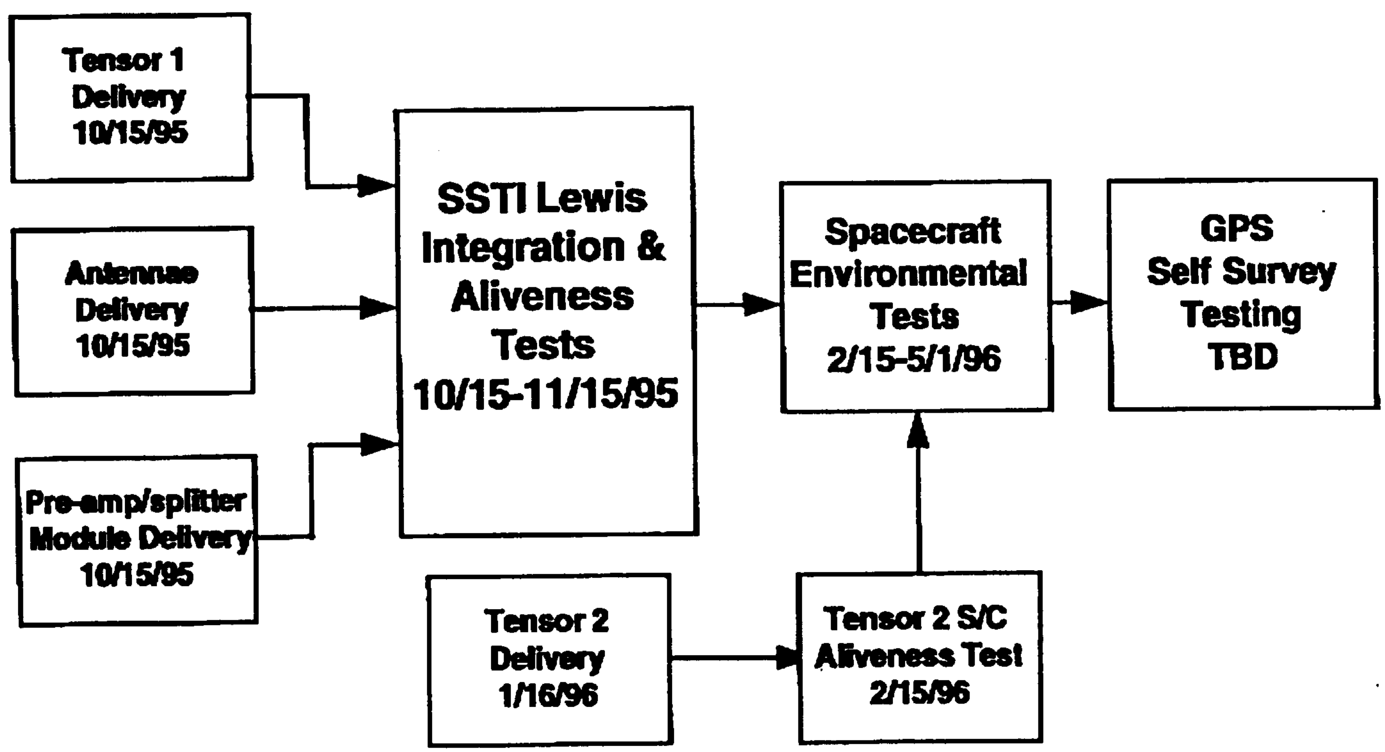
Project: SSTI-Lewis
Date: 1/9/95

Critical | Progress | Summary
Noncritical | Milestone | Rolled Up

GADFLY INTEGRATION AND TEST PLAN



Spacecraft Integration and Testing



STATUS/ISSUES

- Sole source procurement for SS/L Tensor initiated on 12/2/94. CBD announcement 12/22/94. Letter of intent sent 1/10/95. Very little slack in SS/L Tensor delivery to GSFC

- Increased requirements over past 6 months, late delivery of funding, and the need for Tensor has introduced more risk in GADFLY delivery schedule

- Environmental specifications still being negotiated

- Currently have lower data rate than needed (Requested: 5 Kbps; Current baseline: 2.8 Kbps)

- Technique for in-situ calibration test being challenged by TRW

BACKUP SLIDES

TENSOR DESCRIPTION

- First Space Qualified Attitude, Orbit Determination, and Precise Time Sensor to use data derived from Global Positioning System (GPS) constellation of satellites
- Capabilities:
  - Standard Positioning Service (C/A Code) Receiver
  - Attitude Determination Expectations: 0.1° 1σ
  - Precise Time: 1 Pulse-per-second, trailing edge accurate to 1 μsec
  - Orbit Determination:
    - Raw data: 150 meters
    - Filtered expectations from enhanced OD S/W: better than 30 meters
- Available as single string or redundant system
- Uses RAD6000 microprocessor
- 3.85 kg (antennas, preamps & receiver), <12 Watts,
- Class S Parts, 100 KRad Si radiation tolerant

INTEGRATION & TEST FACILITIES

- GADACS GPS Lab, Building 11, Code 712
  - Key Personnel: Jon McCullough, Joel Gambino, Stephen Leake, Scott Leszczynski/USAF, Brian Class/OSC, Larry Jackson/OSC
- Orbit Determination Software Development Facility, Code 712
  - Key Personnel: Stephen Leake/712, Roger Hart/553
- Northern Telecom GPS Attitude/Orbit Simulator, SS/L, Palo Alto, CA
  - Key personnel: Kurt Brock/SS/L, Glenn Lightsey/712, Stephen Leake/712, Roger Hart/553
- GPS Timing Testbed, Building 11, Code 735
  - Key Personnel: Phil Luers, Kelley Johnson, John Allen/DSC

GADACS HARDWARE COMPLEMENT INTERFACE DESCRIPTIONS

Component	Power	Weight	Volume	Data Rate/Type
Patch Antenna (4 required)	0 Watts	0.2 lbs ea	2.9"x2.9"x0.3" ea	N/A
Pre-amp/splitter Module	0 Watts	0.9 lbs	5.4"x2.0"x2.8"	N/A
Tensor Receiver (2 required)	<12 Watts (One on)	6.8 lbs Total	10.8"x6.7"x2.8" Total	2-9600 baud RS-422 Each
RF Cabling	0 Watts	TBD	TBD	N/A

Note: Power & data cabling TRW's responsibility

INTERFACE SPECIFICATIONS

- Power
  - 24 to 38.6 V DC
  - On/off power relay supplied by S/C
  - S/C supplied; 1 for each tensor

- Command and Data Handling
  - RS-422, 9600 Baud, hardware handshaking, 8 bits, odd parity
  - 1 RS-422 port to be utilized per receiver (two ports available)
  - S/C 1553 interface provided by GEM
  - 5 Kbps nominal data rate required
  - Software upload capability shall be supported through GEM
  - All commands generated by ground and sent by S/C OBC
  - Timing pulse (1 pps) provided through 2 differential 1-pps discretes for each Tensor

ENVIRONMENTAL & PERFORMANCE ASSURANCE REQUIREMENTS

- GPS System redundancy required to ensure no single point failures

- 5 year life through S/C radiation environment

- 883B or better parts program

- Environmental test requirements:
  - Vibration: 10.26 Grms Acceptance; 14.14 Grms Protoflight
    - » Acceptance vs protoflight levels still being negotiated with TRW
  - Thermal Vacuum: -29° C to +66° C
    - » Thermal Vacuum vs, Thermal Cycle & temp. excursions still being negotiated with TRW
  - EMI/EMC with GEM

SSTI

NASA

TRW

PAYLOADS & TECHNOLOGY DEMONSTRATIONS

Metal Matrix Heat Strap

G. Casto

Summary:

- The MMCHS should provide a significant (3.5:1 to 4:1) thermal performance increase or weight decrease over conventional copper straps.
  Examples: Passive cooling to CCD's, CryoCoolers heat rejection, Elec. component conduction to card guide.
- Verify the MMCHS thermal performance over the mission life.
- Correlate MMCHS conductivity dependency on temperature.
- Operation scenario has evolved from possible experiment locations.
  (Component simulator held at a constant delta T above radiator Temp.)

Requirements:

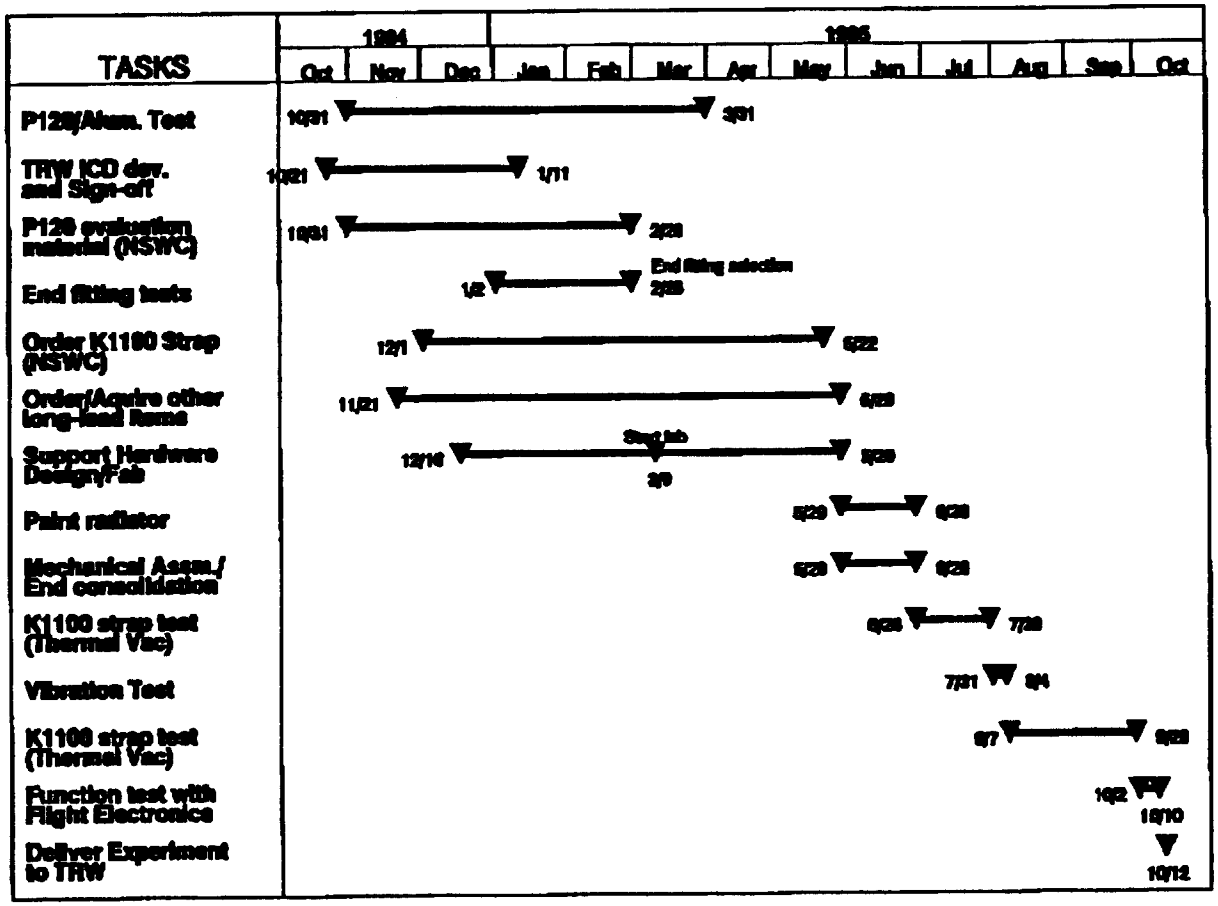
- Operate MMCHS at various temperature regimes (–40-20°C as a min.)
- Collect temperature sensor and heater data from the MMCHS at those regimes.

Item Design:

- The MMCHS has three major components.
  1) metal matrix composite heat strap
  2) component simulator
  3) radiator

- The strap consists of 20, .005" thick, layers of graphite/aluminum (K1100/6063 alloy w/ V_f 35%.) Material provided by NSWC
- The component simulator is aluminum with a heating element attached.
- The radiator is an aluminum plate.
- MLI blanketing where required

Metal Matrix Composite Heat Strap



SSTI-Lewis CDA, January 17-19, 1995
Metal Matrix Composite Heat Strap (MMCHS), Gordon Casto/722.2

Status:

- P120/Alum material procurement started.
- K1100 fiber procurement started. Procurement for K1100/alum. is due soon.
- Final design is pending MMCHS strap location and mechanical interface.
- Electrical and operational interfaces with GEM are defined.

Testing:

- Required testing for the MMCHS will include

  Thermal Vacuum test from -80°C to 50°C
  (temperatures listed are MMCHS imposed limits)

  Random vibration as stated in EV2-099

PAYLOADS & TECHNOLOGY DEMONSTRATIONS

Micromachined Accelerometers

D. Conte

MICROMACHINED ACCELEROMETER TECHNOLOGY DEMONSTRATION

(University of Cincinnati)

Objective

- Demonstrate operation of miniature accelerometers, fabricated using micromachining technology, in space vehicle application

Approach

- Fabricate five micromachined accelerometers with matching signal processing integrated circuits
- Co-locate with five space-qualified SLAM sensors onboard launch vehicle
- Validate micromachined accelerometer operation by comparing data with SLAM sensor data

DESCRIPTION OF THE MICROMACHINED ACCELEROMETERS

Number of accelerometer/IC pairs	5
Accelerometer input range	0 to ±20 g's
Linear frequency range	0 to 100 Hz
Supply voltage	+5 V
Output voltage	0 to +5 V 0 g's = 2.5 V ±20 g's = 0 and +5 V
Power dissipation	< 250 mW
Weight	< 10 g per packaged unit
Package	Each sensor/IC pair will be mounted in a separate 0.46" square flat pack with three pins for external connections. Additional pins for trimming will be as short as possible.
Spacecraft electronic interface	Signal processing IC will interface to a Micro Power Systems MP8799 A/D converter
Spacecraft electrical interface	Three coded wires: 1) +5 V 2) Signal output 3) Signal ground/Power return Wire type and thickness TBD
Spacecraft mechanical interface	TBD

TEST PLAN FOR MICROMACHINED ACCELEROMETERS

Pre-assembly testing

- Extensive chemical/microscopic/mechanical sequential semiconductor processing evaluations in MEMS
- Visual inspection of accelerometer
- Shake table electrical evaluation to meet specifications
- Verify IC's using automated test measurements

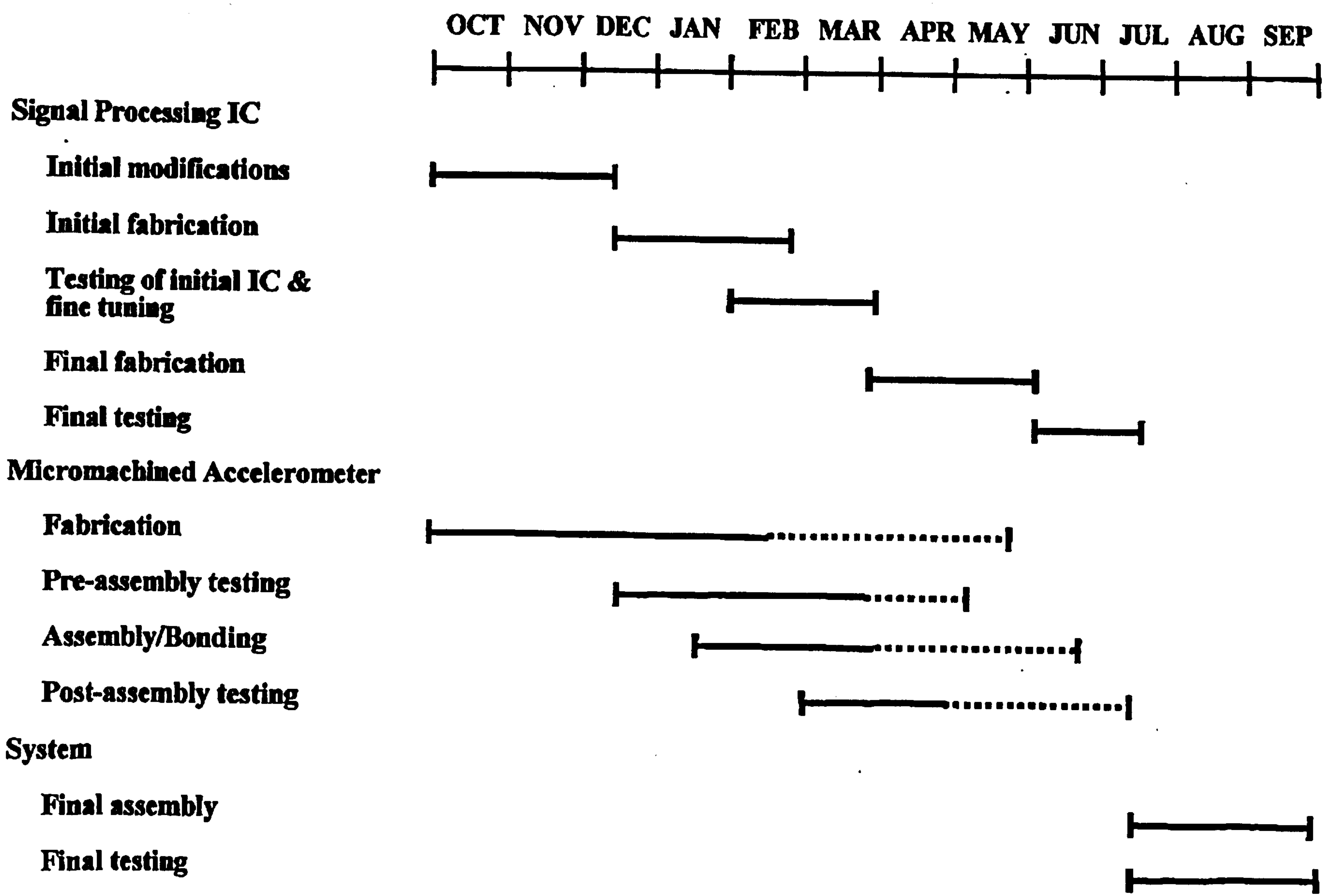
Packaging

- Visual
- Shake table on bonding mock-up to composite material (if available)

Post-assembly testing

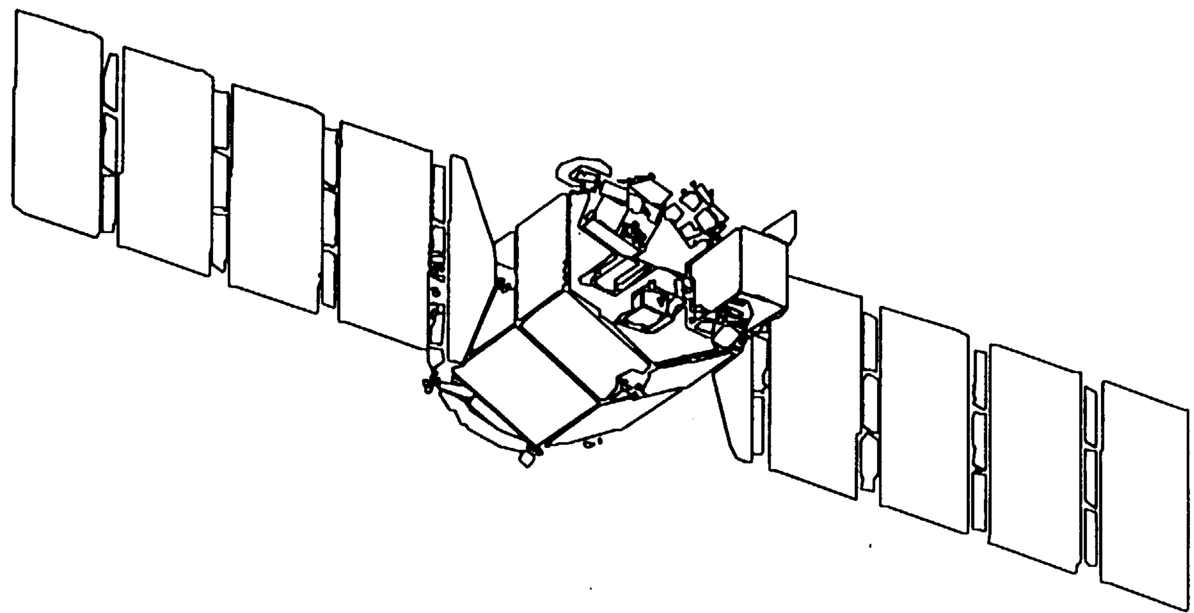
- Measure sensitivity of the accelerometer
- Measure accelerometer temperature coefficients
- Trim device based on system level measurements

MICROMACHINED ACCELEROMETER/SIGNAL PROCESSING IC SCHEDULE



pdb

Small Satellite Technology Initiative
(SSTI Lewis Spacecraft Program)

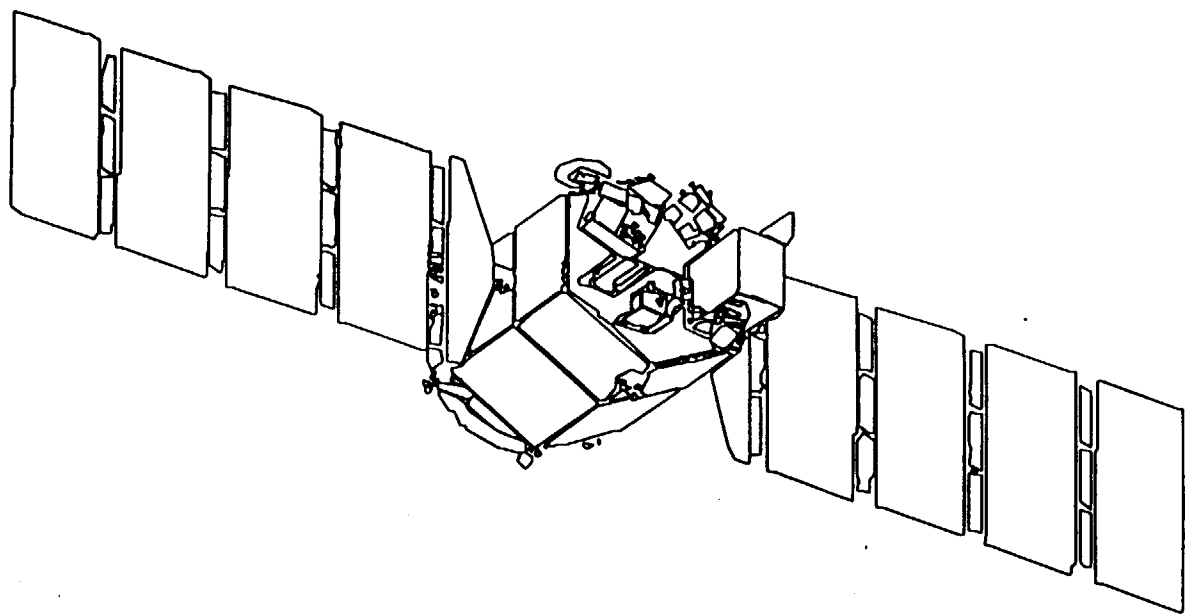


System Critical Design Audit (CDA)

January 17-19, 1995

Book 3 of 3

Small Satellite Technology Initiative
(SSTI Lewis Spacecraft Program)



System Critical Design Audit (CDA)

January 17-19, 1995

Book 3 of 3

SSTI-LEWIS CDA AGENDA, DAY 1
TUESDAY, 17 JANUARY 1995

TIME	TOPIC	PRESENTER
10:00 - 10:10	Welcome & Introduction	Watkins/Sabelhaus
10:10 - 10:20	Program Overview	Marshall
10:20 - 10:50	Technical Overview	Biber/Taylor
	SYSTEM REQUIREMENTS	
10:50 - 11:10	Performance	Taylor
11:10 - 11:40	Verification	Belte
11:40 - 12:10	Mission Assurance	Niemela
12:10 - 13:00	Lunch	
	SCIENCE & COMMERCIAL APPLICATIONS	
13:00 - 13:15	Overview	Pearlman
13:15 - 13:45	Mission Data Management System	Witcher
13:45 - 14:05	Education	Woods, M.
14:05 - 14:25	Applications Development	Pearlman
14:25 - 14:40	Data Policy	Watkins
	GROUND SEGMENT	
14:40 - 14:50	Overview	Sarina
14:50 - 15:20	Requirements	Berman
15:20 - 15:35	Break	
15:35 - 16:05	CDRS Design	Taylor (Harris)
16:05 - 16:35	SOCC Design	Berman
16:35 - 17:15	Mission Operations	Zion

SSTI

SSTI-LEWIS CDA AGENDA, DAY 2
WEDNESDAY, 18 JANUARY 1995

TRW

TIME	TOPIC	PRESENTER
	SPACECRAFT INTEGRATION, TEST, & LAUNCH	
8:30 - 8:45	Design Summary	Woods, D.
8:45 - 9:30	Mechanical Design Integration	Norden
9:30 - 10:15	Electrical Design Integration	Woods, D.
10:15 - 10:30	Break	
10:30 - 12:00	System Integration & Test	Brooks
12:00 - 12:45	Lunch	
12:45 - 13:30	Launch Interface & Operations	Turner/Desilets
	PAYLOADS & TECHNOLOGY DEMONSTRATIONS	
13:30 - 13:45	Overview	Conte
13:45 - 14:30	HSI	Marmo
14:30 - 15:00	LEISA	Reuter
15:00 - 15:15	Break	
15:15 - 15:45	UCB	Edelstein
15:45 - 16:00	Recorder Interface Module (RIM)	Hayes
16:00 - 16:10	GEM/SLAM	Luers
16:10 - 16:20	Multi-junction GaAs Solar Cells	Slifer
16:20 - 16:30	Amorphous Silicon Solar Cells	Starritt
16:30 - 16:40	ASCE Electronics Design	Larrick
16:40 - 16:55	GPS Attitude Determination	Bauer
16:55 - 17:05	Metal Matrix Heat Strap	Casto
17:05 - 17:15	Micromachined Accelerometers	Conte

SSTI-LEWIS CDA AGENDA, DAY 3
THURSDAY, 19 JANUARY 1995

TIME	TOPIC	PRESENTER
	PAYLOADS & TECH DEMOS (CONTINUED)	
8:30 - 8:40	Lossless Data Compression Module	Fong
8:40 - 8:50	Lossy Data Compression	Yeh
8:50 - 9:00	GPC	Shinn
9:00 - 9:15	Cloud and Feature Editing	Davis
9:15 - 9:25	WFOV Star Tracker	Parry
9:25 - 9:35	Mag. Suspended Reaction Wheel	Gerson
9:35 - 9:45	MOCK	Gerson
9:45 - 9:55	Enhanced ACS	Maghami
9:55 - 10:05	On-Orbit ID	Elliott
10:05 - 10:20	PEA/OPA/Cryocoolers	Gerson
10:20 - 10:25	New Experiments	Conte
10:25 - 10:30	Summary	Conte
10:30 - 10:45	Break	
	SPACECRAFT BUS	
10:45 - 11:00	Overview	Biber
11:00 - 11:30	Structure & Mechanisms	Barrett
11:30 - 11:50	Thermal Control	Biber
11:50 - 12:20	Propulsion	Joseph
12:20 - 13:15	Lunch	
13:15 - 13:45	Electrical Power & Distribution	Starritt
13:45 - 14:15	GN&C	Parry
14:15 - 15:15	Data Management Subsystem	Almeida
15:15 - 15:30	TT&C	Schall
15:30 - 15:45	Break	
15:45 - 16:30	Spacecraft Software	Stafa/Smith
	CLOSURE	
16:30 - 16:50	Program Milestone Summary	Lane
16:50 - 17:00	Closing Remarks	Watkins/Sabelhaus

PAYLOADS & TECHNOLOGY DEMONSTRATIONS

Lossless Data Compression Module

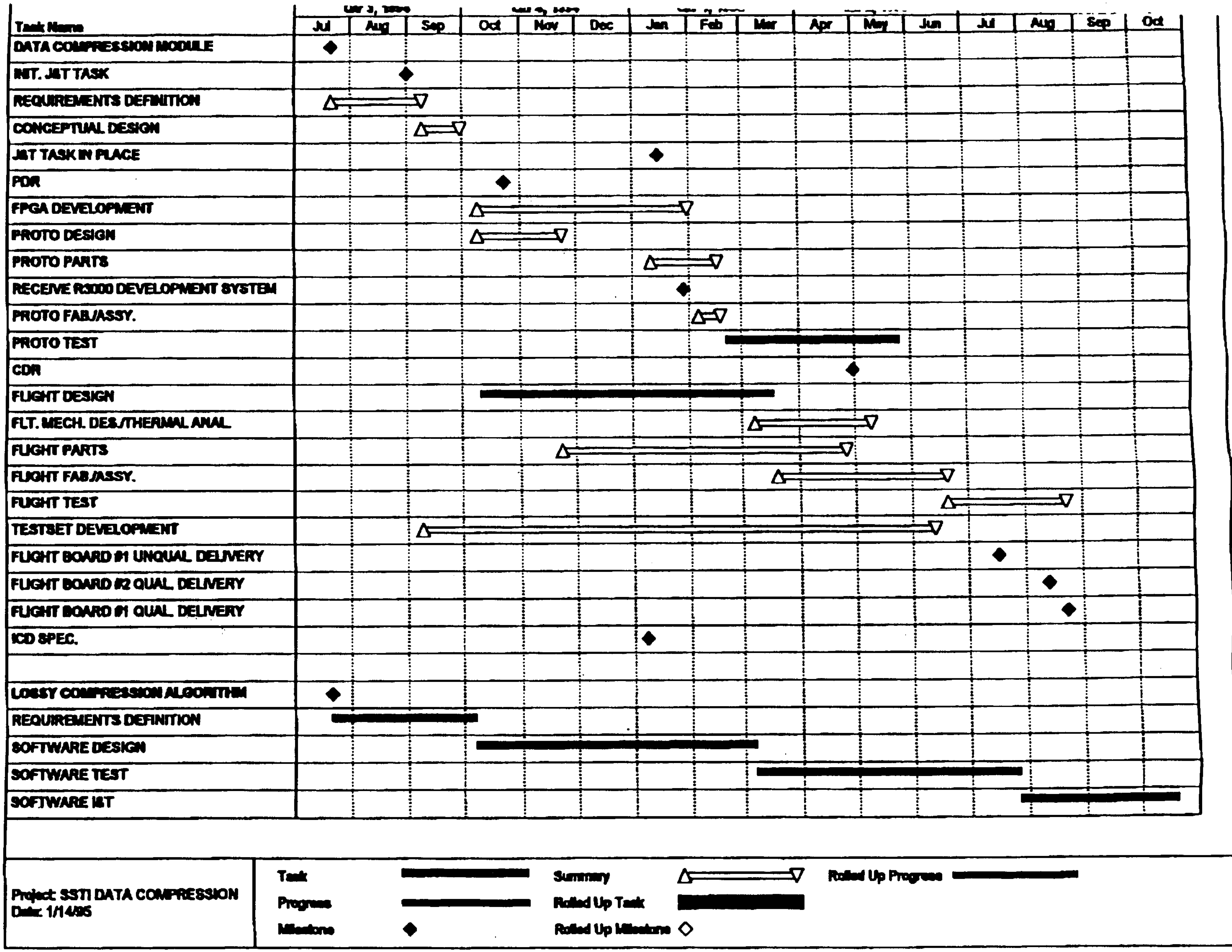
W. Fong

DCM DESCRIPTION

DCM PROJECT DESIGNED TO MITIGATE LIMITED DATA STORAGE CAPABILITY IN SSR.

DCM WILL PROVIDE LOSSLESS DATA COMPRESSION FOR HSI AND LEISA INSTRUMENTS UTILIZING RICE ENCODING ALGORITHM FROM THE USES IC.

A MIL-1553B BUS CONTROLLER CIRCUITRY IS INCORPORATED ON-BOARD FOR MAIN SPACECRAFT COMMUNICATIONS.



Project: SSTI DATA COMPRESSION
Date: 1/14/95

REQUIREMENTS/CAPABILITIES/VERIFICATION

REQUIREMENT	CAPABILITIES	VERIFICATION
PROVIDE LOSSLESS DATA COMPRESSION	LOSSLESS DATA COMPRESSION PROVIDED BY USES IC	TESTING
256 SAMPLES/PACKET	$\leq$1024 SAMPLES/PACKET	TESTING
8, 12, 13 BITS/SAMPLES	4-15 BITS/SAMPLE, PROGRAMMABLE	TESTING
NEAREST NEIGHBOR PREDICTOR	NEAREST NEIGHBOR PREDICTOR (OPT. ENTROPY CODING), NON-COMPRESSING PACKETIZING MODE (BYPASS)	TESTING
MIL-1553B BUS CONTROLLER	MIL-1553B BUS CONTROLLER USING SμMMIT IC	TESTING

DCM STATUS

FPGA DESIGN TO BE COMPLETED BY END OF JANUARY '95.

PROTYPE BOARD DESIGN COMPLETED.

PROTOTYPE PARTS ON ORDER.

R3000 DEVELOPMENT SYSTEM DUE BY END OF JANUARY '95.

MIL-1553B BTE ALLOCATED FOR PROJECT.

TEST APPROACH

DEVELOP PROTOTYPE BOARD FOR DESIGN VERIFICATION

UTILIZE TRW PROVIDED R3000 DEVELOPMENT SYSTEM FOR OBC FUNCTIONAL VERIFICATION

CALIBRATE DCM USING TRW PROVIDED HSI SENSOR DATA AND GSFC PROVIDED LEISA SENSOR DATA

USE IN-HOUSE MIL-1553B BTE FOR 1553B INTERFACE

DEVELOP TESTSET SOFTWARE FOR VERIFICATION OF 1553B AND DATA COMPRESSION INTERFACE

PERFORM FUNCTIONAL AND TIMING VERIFICATION OF UNQUALIFIED FLIGHT BOARD #1 AND ONE THERMAL CYCLE TEST BEFORE DELIVERY TO TRW.

PERFORM FUNCTIONAL AND TIMING VERIFICATION OF FLIGHT BOARD #2 WITH WORKMANSHIP TEST BEFORE DELIVERY TO TRW.

PERFORM WORKMANSHIP TEST OF FLIGHT BOARD #1 WHEN RECEIVED FROM TRW.

ASSIST IN FUNCTIONAL AND ENVIRONMENTAL TESTING OF FLIGHT BOARDS IN SPACECRAFT COMPUTER.

PAYLOADS & TECHNOLOGY DEMONSTRATIONS

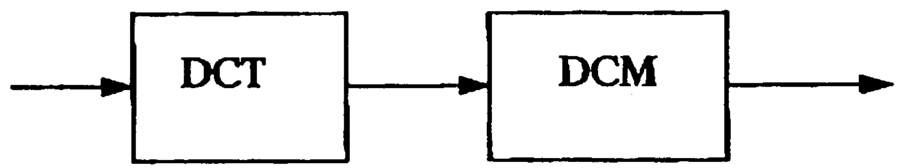
Lossy Data Compression

P. Yeh

HIGH PERFORMANCE DATA COMPRESSION (HPDC)

THE BASELINE HPDC WILL IMPLEMENT DISCRETE COSINE TRANSFORM (DCT) AS THE PRE-PROCESSOR TO THE DCM HARDWARE FOR THE FOLLOWING SSTI PAYLOAD SENSOR DATA.

1. HYPER SPECTRAL IMAGER (HSI)
2. LINEAR ETALON IMAGING SPECTRAL ARRAY (LEISA)



HIGH PERFORMANCE DATA COMPRESSION (HPDC)

REQUIREMENT VS. CAPABILITIES

REQUIREMENT	CAPABILITY
PROVIDE LOSSY DATA COMPRESSION	PROVIDE LOSSY DATA COMPRESSION USING A DCT ALGORITHM IN SOFTWARE (TRANSFORM BOX SIZE 16x16
COMPRESSION RATIO 10, 20, 40 TO 1	SELECTABLE BY COMMAND 5< CR< 80
8, 12, 13 BITS/SAMPLE	SELECTABLE FROM 8 TO 16 BITS/SAMPLE

HIGH PERFORMANCE DATA COMPRESSION (HPDC)

STATUS:

- Completed coding of baseline algorithm for both compression and decompression.
- Currently performing test using software codes for the DCM function.
- Currently testing on simulated HSI data sets.
- Working on the design of quantization table.

ISSUES:

- Simulated HSI data does not truly represent flight data, may affect Q-table design

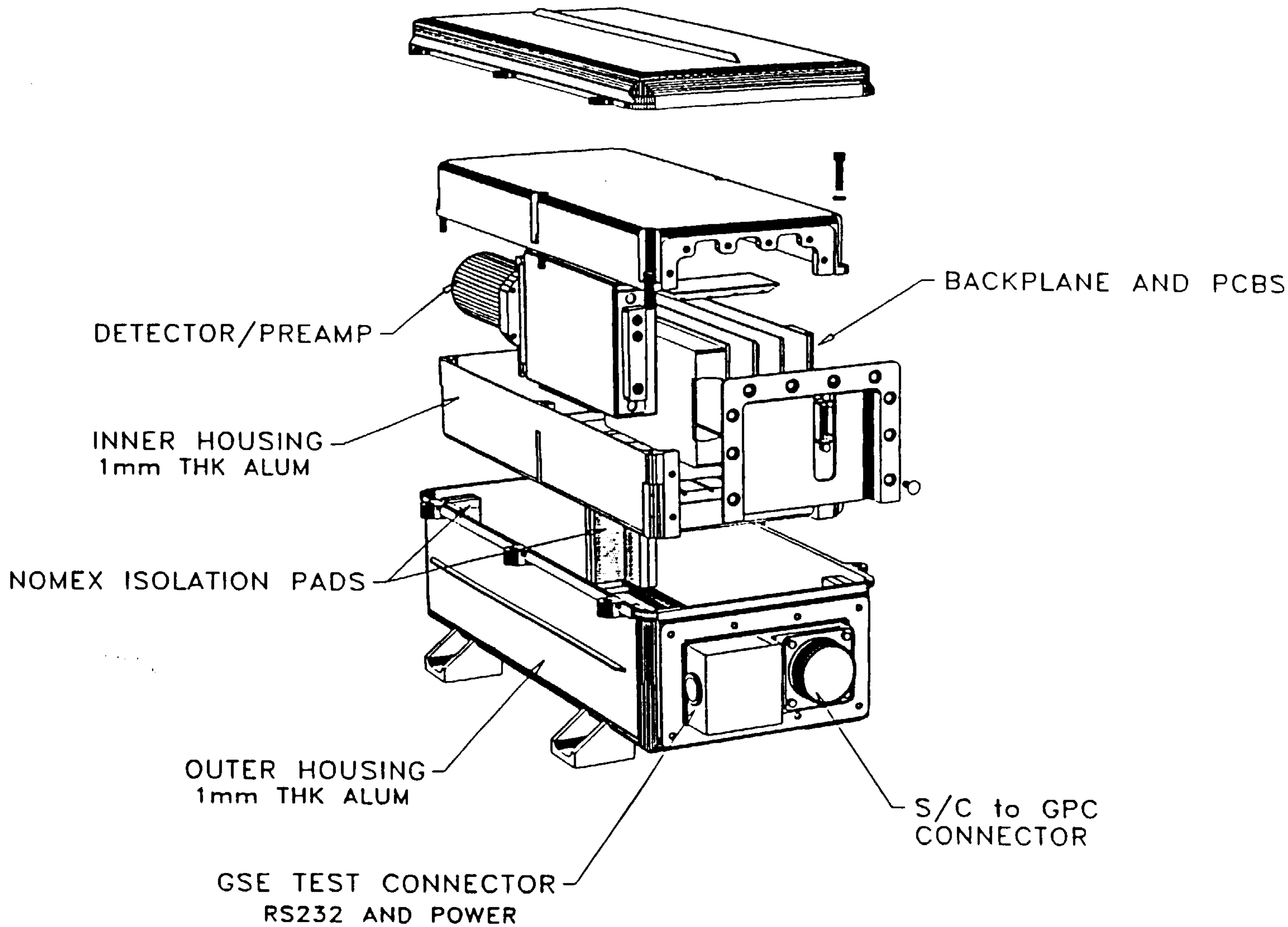
  Quantization: 8-bit (simulated) vs. 12-bit (actual)

  Resolution: 5-6m(simulated) vs. 30m(actual)

  Bands: 458-885nm(simulated), 4.8nm/band vs. 400-2500nm(actual) for VNIR, SWIR
- No LEISA test data yet.

PAYLOADS & TECHNOLOGY DEMONSTRATIONS
GPC

J. Shinn



GPC EXPERIMENT

GPC DESCRIPTIONS

- Measure LET spectrum of radiation in LEO from 0.3 to 1250 keV/μm
- Low pressure gas in detector; operate in linear portion of gas gain vs. voltage regime
- Amplified voltage outpuut is pulse height analyzed in a 256 channel ADC
- Resolution: 0.1 keV/μm below 20 keV/μm
5.0 keV/μm above 20 keV/μm
- Full spectrum recorded every minute on RAM
- Less than 2.5% gain shift within 50 - 70 degree C
- Normally operated with 1553 I/F disabled except for about 5 minutes per day for downloading science data

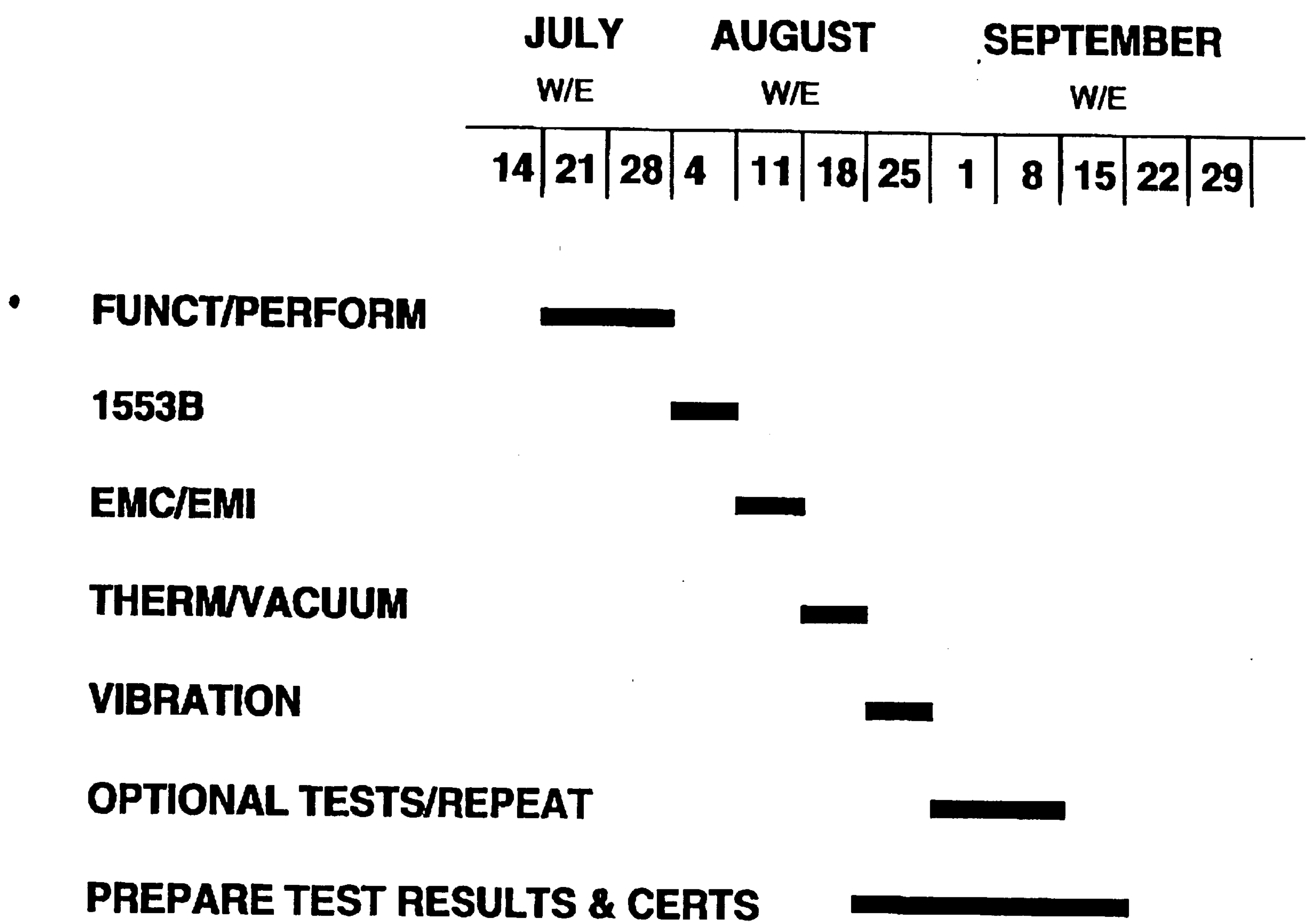
GPC Development Schedule

- Completed design for bus interface and power supply for1553B card
- Layout, purchase PCB boards and parts, and assembly (1/15-2/28/95)
- Complete mechanical housing (1/15-2/28/95)
- Preliminary 1553 testing (3/1-4/30/95)
- Testing of GPC (w/o 1553); incorporate 1553 and testing (5/1-6/30/95)
- Flight certification tests (7/7-9/15/95)
- Software development (3/1-9/15/95)
- Recalibrate GPC (9/15-10/7/95)
- Deliver GPC and some documentation (10/15/95)

GPC STATUS

- Completed 1553B design (JSC)
- Fit 1553B and static RAM on the same board (JSC/Bartelle);
  Decide on part manufacturer (product availability, size, and power)
- Contract placed to Bartelle for fabrication of GPC without 1553B
- Soon start working on external housing, pending on availability of connector from Amphenol
- Outlined command and command format; Scheduled completion January 95
- Ongoing discussion with D. Antoniuk about cooler attach plate temperature for longer GPC design life

GPC TEST PLAN



PAYLOADS & TECHNOLOGY DEMONSTRATIONS

Cloud and Feature Editing

D. Davis

CLOUD AND FEATURE EDITING TECHNOLOGY DEMONSTRATION EXPERIMENT FOR TRW SSTI *LEWIS* SPACECRAFT

CDA UPDATE

17-19 January 1995

Richard E. Davis
Remote Sensing Technolgy Branch
Aerospace Electronic Systems Division
NASA Langley Research Center
(804) 864-1647
FAX (804) 864-8809

CLOUD AND FEATURE EDITING TECHNOLOGY DEMONSTRATION EXPERIMENT– UPDATE AT TRW SSTI *LEWIS* CDA

CONTENTS

- **STATUS/PLANS SUMMARY :**
  - -- Cloud/Feature Editing Algorithm
  - -- Cloud Forecast/Validation Support
- **CLOUD/FEATURE EDITING ALGORITHM :**
  - -- Review of Algorithm Basics(Feature ID With Linear Discriminant Functions)
  - -- Algorithm Enhancements: Background and Rationale
  - -- Sample Simulations for 1.38 micron channel
  - -- Assumptions/Inputs Needed
  - -- Logic Flow Chart
- **ISSUES/CRITICALITY/SCHEDULE IMPACTS :**
  - -- Cloud/Feature Editing Algorithm
  - -- Cloud Forecast/Validation Support

CLOUD AND FEATURE EDITING
TECHNOLOGY DEMONSTRATION EXPERIMENT

STATUS/ PLANS SUMMARY AT CDA

- **CLOUD/FEATURE EDITING ALGORITHM :**

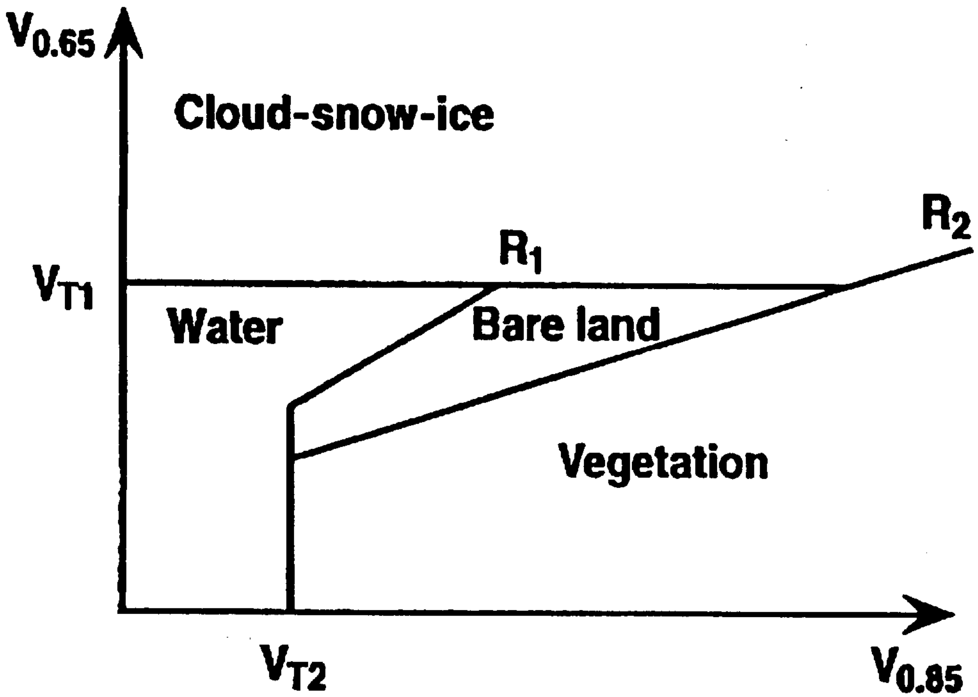
  - Improved Algorithm Developed. 1.38 micron channel added, to make 5-channel concept. Logic tested in atmospheric radiative transfer simulations. New channel allows detection/ rejection of high altitude cloud-contaminated pixels.

  - Remainder of logic(4 channels) unchanged from enhanced *FILE*-based concept presented at ICDA # 1,Oct.,1994, which discriminates between surface feature /low-alt. cloud types.
  - Test of algorithm on *AVIRIS* data planned for 3/95 time frame.
  - Preliminary source-code logic under development. Completion goal 5/95.
  - On schedule for 7/95 delivery of operational code.
  - Ground-processing code delivery goal 9/95.

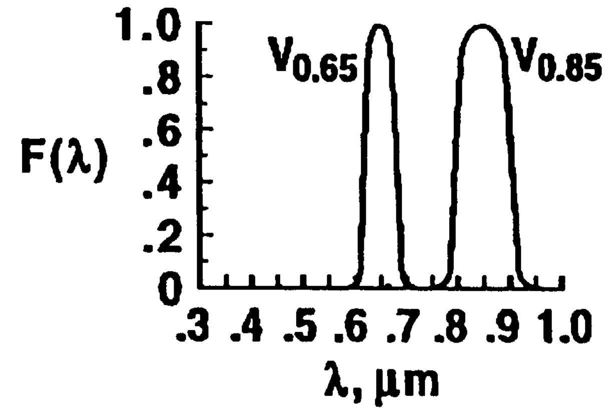
- **CLOUD FORECAST/VALIDATION SUPPORT :**

  - Contacts with USAF/RTNEPH continuing. Pressing for USAF Commitment statement in 3/95 time frame.
  - Alternate support approach concept being developed as contingency.
  - No SSTI mission impacts for some time yet, but desirable to confirm commitment as early as possible.

FEATURE IDENTIFICATION WITH LINEAR DISCRIMINANT FUNCTIONS



Channels for Clark/WV imager



Boundaries (Preliminary):

R_1: $V_{0.65} = 1.18\, V_{0.85} + 0.1$

R_2: $V_{0.65} = 0.694\, V_{0.85} + 0.2$

Thresholds V_{T1} and V_{T2} depend on solar zenith angle

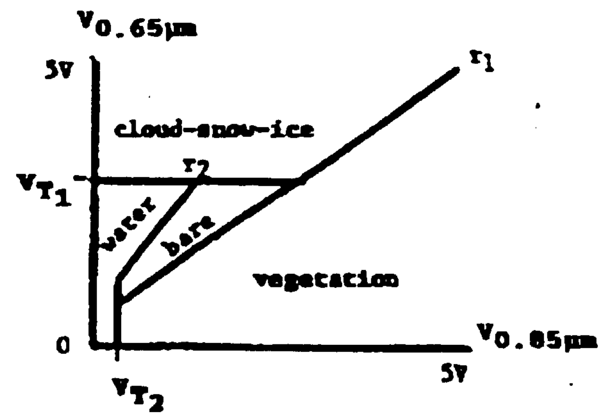
Enhancements for Lewis HSI

- 1.55 μm IR channel to discriminate cloud/snow or ice
- 1.25 μm IR channel to discriminate snow/ice
- 1.38 μm IR channel to detect high clouds

GFTR dd95-256

CLOUD/FEATURI DENTIFICATION ALGORITHM (ADVANCED *FILE* CONCEPT)

(a) INITIAL CLASSIFICATION FOR ALL PIXELS



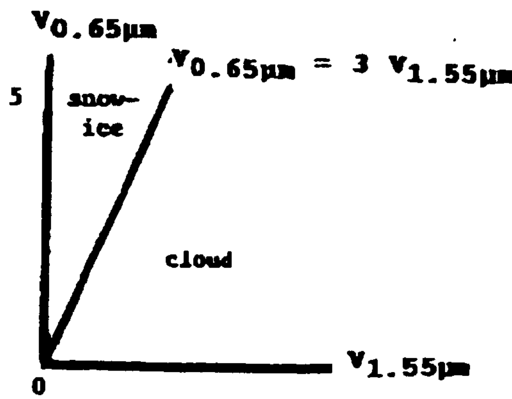
V_{T_1} = 1.15V for low sun angle
= 1.90V for high sun angle

V_{T_2} = 0.45V for low sun angle
= 0.73V for high sun angle

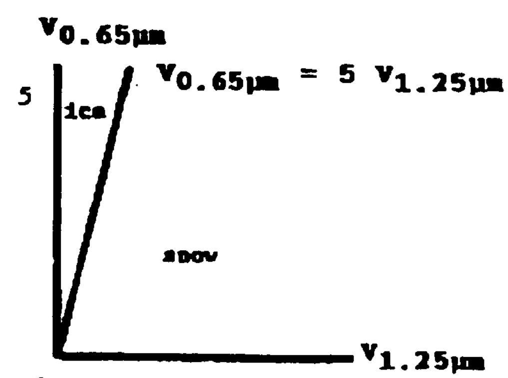
r_1: $V_{0.65\mu m} = 0.694\ V_{0.85\mu m} + b_1$ $\quad b_1 = 0.2$ Volts

r_2: $V_{0.65\mu m} = 1.18\ V_{0.85\mu m} + b_2$ $\quad b_2 = 0.1$ Volts

(b) CLASSIFICATION BETWEEN CLOUD AND SNOW/ICE PIXELS



(c) CLASSIFICATION BETWEEN SNOW AND ICE PIXELS

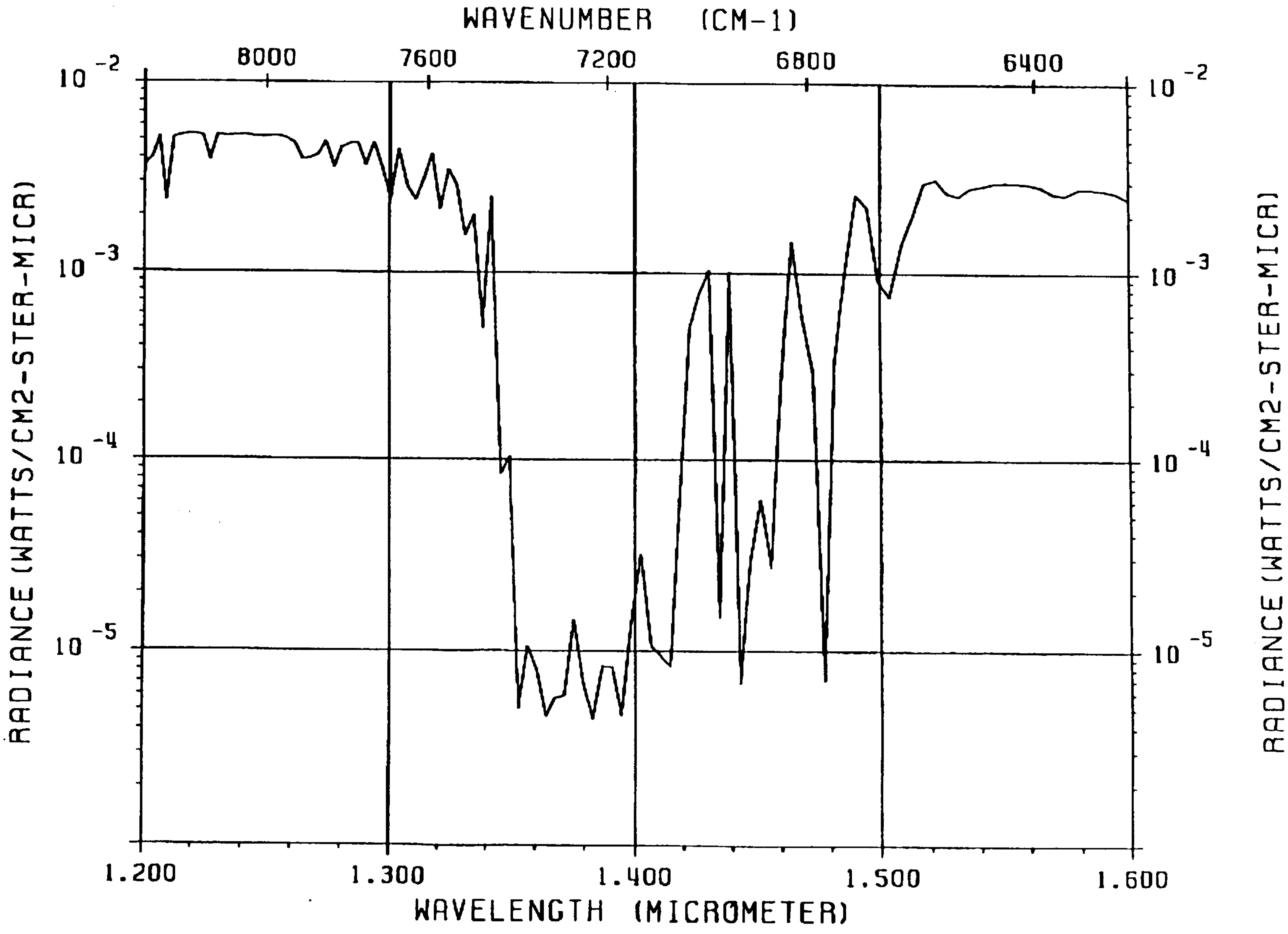


CLOUD AND FEATURE EDITING
TECHNOLOGY DEMONSTRATION EXPERIMENT
ALGORITHM ENHANCEMENTS/RATIONALE

- DR. B.-C.GAO @ NASA-GODDARD RECOMMENDED 1.38 MICRON CHANNEL FOR HIGH ALTITUDE CLOUD DETECTION. THIS CHANNEL OPAQUE AT LOW ALTITUDES, AND INSENSITIVE TO SURFACE REFLECTANCE VARIABILITY.
- 1.38 MICRON RADIANCE SIMULATIONS INDICATE ABILITY TO DETECT CLOUDS RELIABLY FOR ALTS. > 4KM.--THUS,TO DETECT WEATHER FRONT CLOUD SHIELDS.
- OFFERS POTENTIAL OF SINGLE SPECTRAL CHANNEL- METHOD OF IDENTIFYING HIGH ALTITUDE CLOUDS IN SCENE. MAY OFFER REAL-TIME EDITING CAPABILITY, (REMOVING PIXEL OVERLAY/CHANNEL RATIOING REQUIREMENTS OF ORIGINAL CONCEPT, WHICH MANDATES DELAYED PROCESSING).
- 1.38 MICRON CHANNEL ADDED TO ORIGINAL FOUR-CHANNEL ALGORITHM, TO FORM NEW,TWO-LEVEL LOGIC:
  FIRST LEVEL : HIGH ALT. CLOUD DETECTION
  SECOND LEVEL : LOW-ALT.CLOUD/FEATURE EDITING
- BOTH LEVELS NECESSARY TO DO 'COMPLETE CLOUD DETECTION' JOB.
- BOTH LEVELS TO BE EVALUATED IN EXPERIMENT(CF. FLOW DIAGRAM).
- MISSION SUCCESS ENHANCED, THROUGH ABILITY TO DETECT HIGH-ALTITUDE CLOUDS' PRESENCE,USING A SIMPLE TECHNIQUE AND INHIBIT IMAGE GATHERING. CHANCE OF REAL-TIME EDITING OF CLOUD-FREE PIXELS GREATLY ENHANCED.

MODTRAN RADIANCE SIMULATION

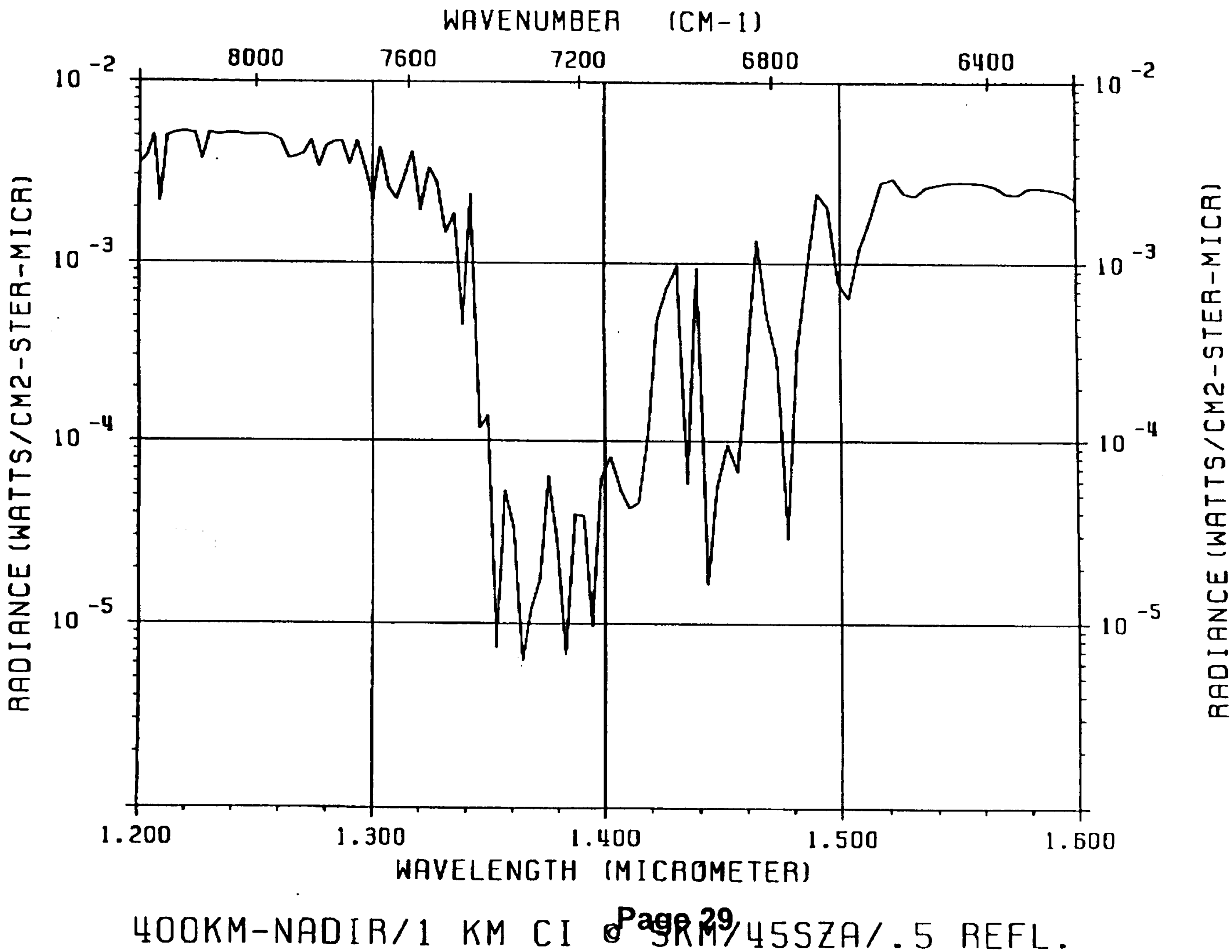
A. NADIR, .5 REFLECTANCE, NO CLOUDS



400-0KM/0NVA/23KRAZ/.5REFL./45SZA

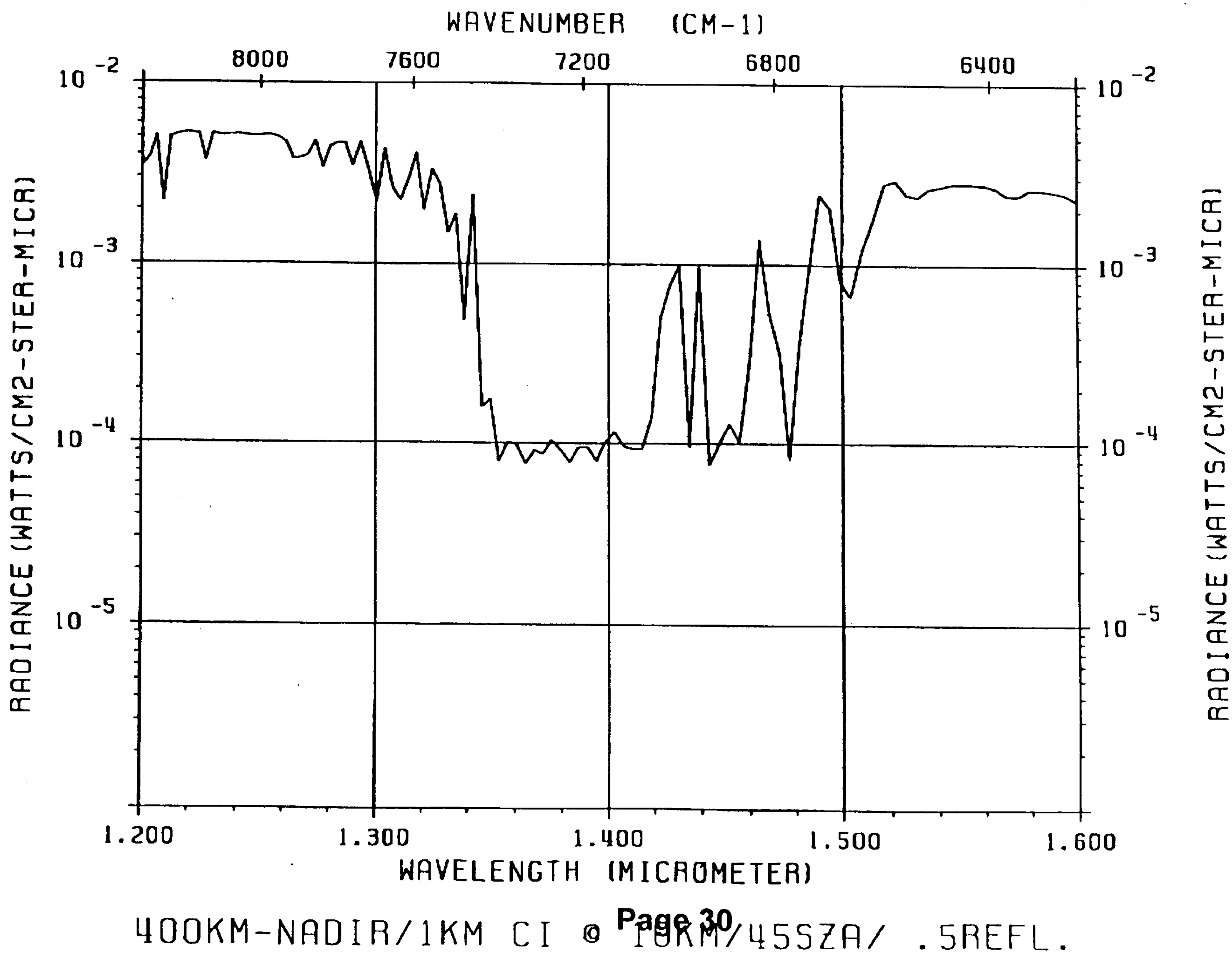
***MODTRAN* RADIANCE SIMULATION**

B. <u>AS A., BUT 1 KM CIRRUS AT 5 KM ALTITUDE</u>
(note behavior around 1.38 microns)



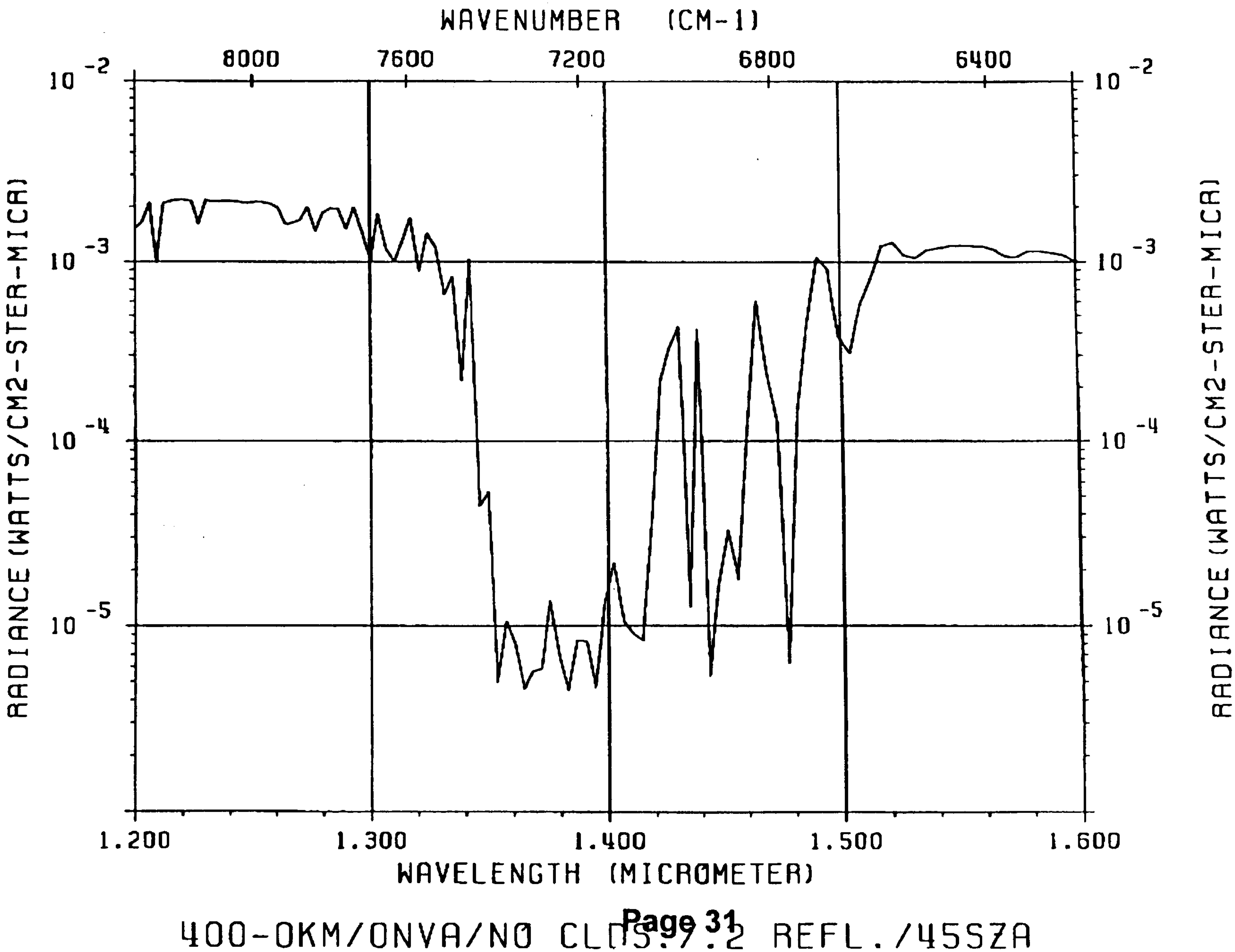
MODTRAN RADIANCE SI(ATION

C. AS A., BUT 1 KM CIRRUS AT 10 KM ALTITUDE
(Note marked radiance increase in 1.35 - 1.40 micron region)



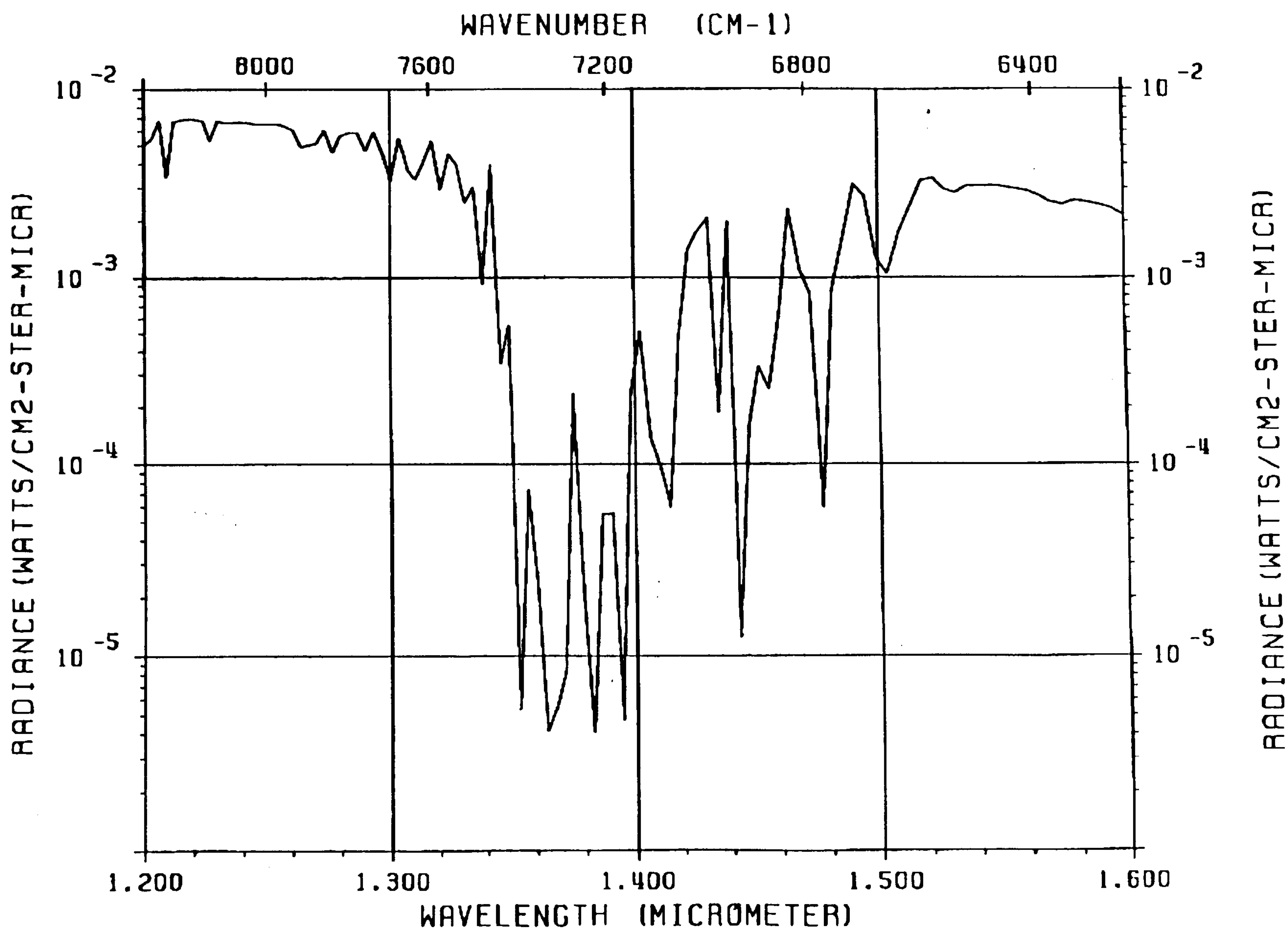
D. <u>AS A., BUT 0.2 REFLECTANCE</u>

(Note insensitivity to reflectance around 1.38 microns)



E. LOW -ALT. CU DECK, TOPS 3 KM

(Note minimal difference from A., @ 1.38 microns, insensitivity @ 1.38 to low altitude clouds)



400KM-NADIR/CU TOPS 3KM/45SZA/.5REFL.

CLOUD/FEATURE EDITING
TECHNOLOGY DEMONSTRATION EXPERIMENT
ASSUMPTIONS, AND INPUTS NEEDED FOR ALGORITHM

- ASSUME GEOGRAPHICALLY COINCIDENT PIXELS, REGISTERED IN FIVE SPECTRAL CHANNELS, ARE AVAILABLE.

- ASSUME RADIANCE-TO- VOLTAGE CALIBRATIONS AVAILABLE IN FIVE CHANNELS, NOMINALLY AT 0.65, 0.85, 1.25, 1.38, 1.55 MICRONS. (NEEDED TO REFINE ALGORITHM SLOPES AND INTERCEPTS)

- NEED SOLAR ILLUMINATION/VIEW GEOMETRY PARAMETER VALUES FOR PIXEL:
  -- Solar Zenith Angle(SZA)
  -- Nadir View Angle(NVA)
  (These may be calculated from Satellite Geographic Position and HSI LOS pointing angles, vs. time).

  -- SZA,NVA needed to assign algorithm threshold voltages VT0,VT1,VT3 for pixel; Table lookup will be used,part of algorithm.
  (To be developed in *AVIRIS* simulations)

CLOUD AND FEATURE EDITING TECHNOLOGY DEMONSTRATION EXPERIMENT

ENHANCED ALGORITHM

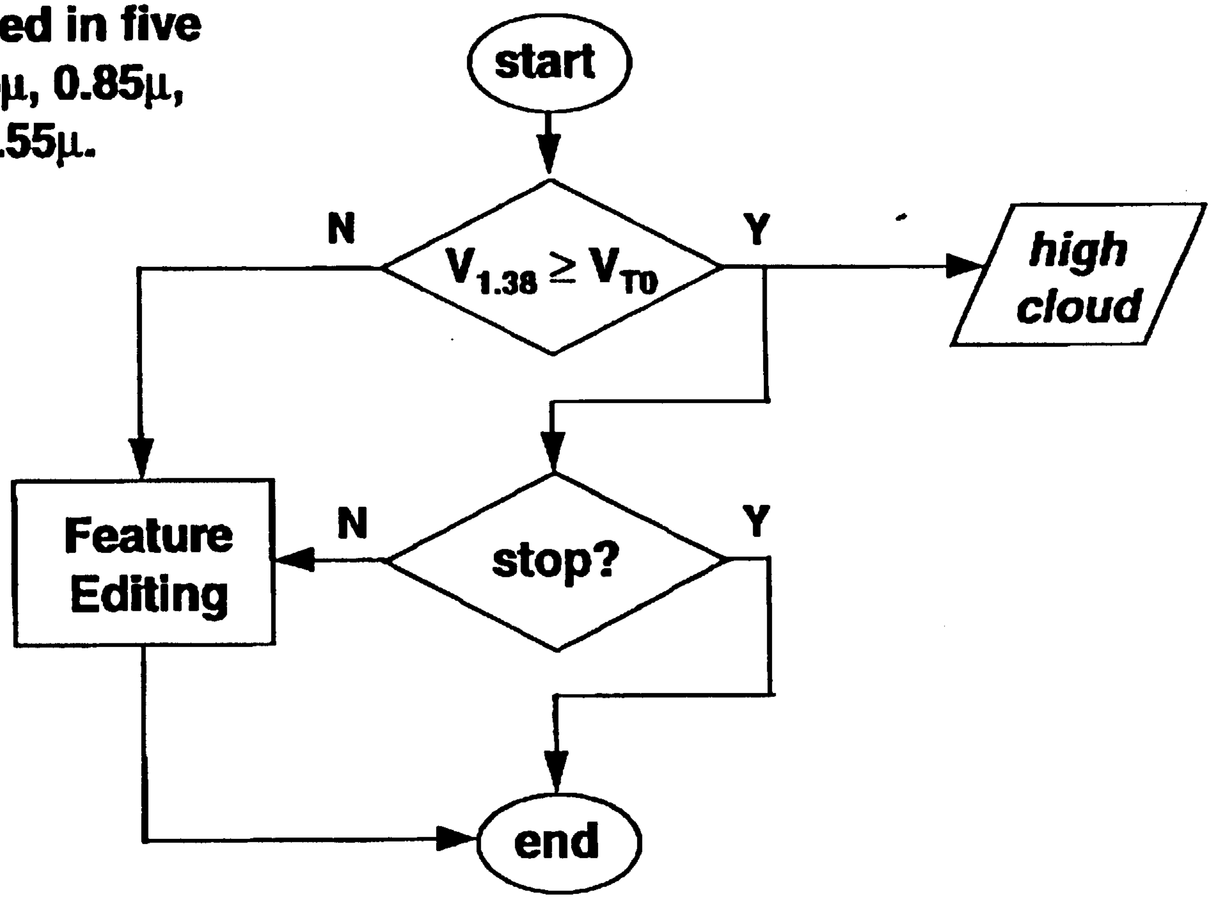
ENHANCED ALGORITHM CONTAINS TWO STAGES:

- High Altitude Cloud Detection, with option to terminate processing.
- Feature Editing(Low-alt. clouds, and surface features)

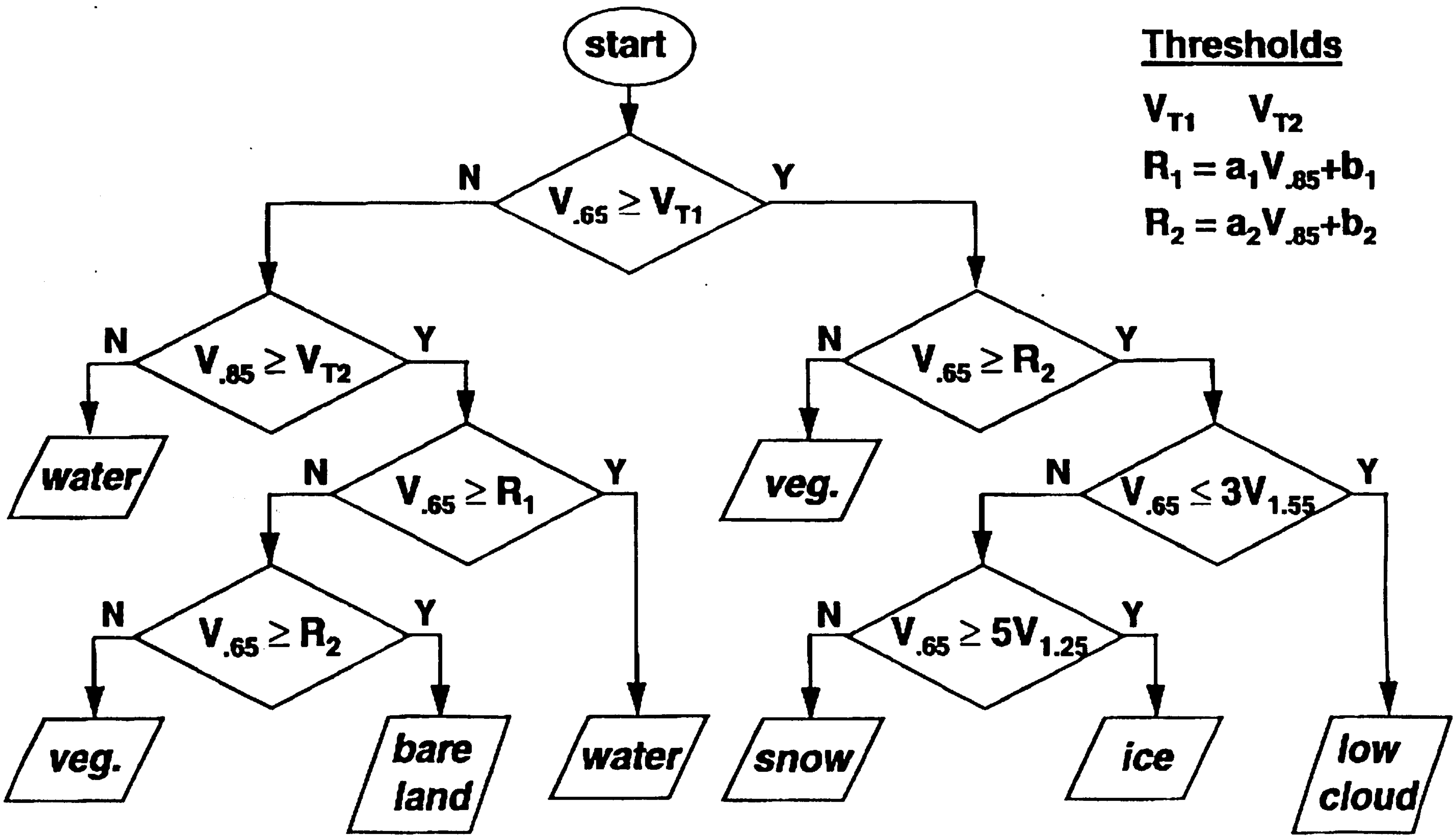
LOGIC FLOW FOR TWO STAGES SHOWN ON NEXT TWO PAGES

High Altitude Cloud Detection Logic Per Pixel

Pixels registered in five channels: 0.65μ, 0.85μ, 1.25μ, 1.38μ, 1.55μ.



Feature Editing Algorithm Logic Per Pixel



Thresholds

V_{T1} V_{T2}

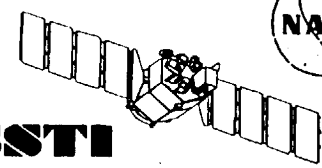
$R_1 = a_1 V_{.85} + b_1$

$R_2 = a_2 V_{.85} + b_2$

CLOUD AND FEATURE EDITING
TECHNOLOGY DEMONSTRATION EXPERIMENT

ISSUES

ISSUE / RESPONSIBILITY :	UNKNOWN(S) :	CRITICALITY / (NEED DATE) :
1. SPECTRAL PIXEL COINCIDENCE, IN FIVE CHANNELS / (TRW)	CAN IT BE ACHIEVED ? DEGREE OF PIXEL OVERLAP	ESSENTIAL FOR FULL ALGORITHM FUNCTION/ TECH. DEMO. (12/95)
2. RADIANCE-TO-VOLTAGE CALIBRATIONS, AND CHANNEL SPECTRAL RESPONSES IN FIVE CHANNELS OF ALGORITHM / (TRW --MARMO)	AVAILABILITY DATE	ESSENTIALFOR ALGORITHM SIM'S.ON *AVIRIS* DATA, WITH HSI CHANNELS. (2/95) ESSENTIALFOR USE IN FINAL THRESHOLD DEVELOPMENT FOR HSI ALGORITHM. (4/95)
3. SOLAR ILLUMINATION/ LOS VIEW GEOM. AT PIXEL /(???)	WHO WILL PROVIDE ?	TO SET ALGORITHM THRESHOLD LEVELS VT0,VT1,VT2. (6/95)
4. CLOUD FORECAST/VALIDATION SUPPORT ARRANGEMENTS/ (LaRC--DAVIS)	WHO: USAF/ETAC ?	TIMELY AGREEMENT NEEDED FOR OPTIMAL INTEGRATION INTO SSC MISSION DATA MANAGEMENT PLAN. (6/95)



PAYLOADS & TECHNOLOGY DEMONSTRATIONS
WFOV Star Tracker

P. Parry

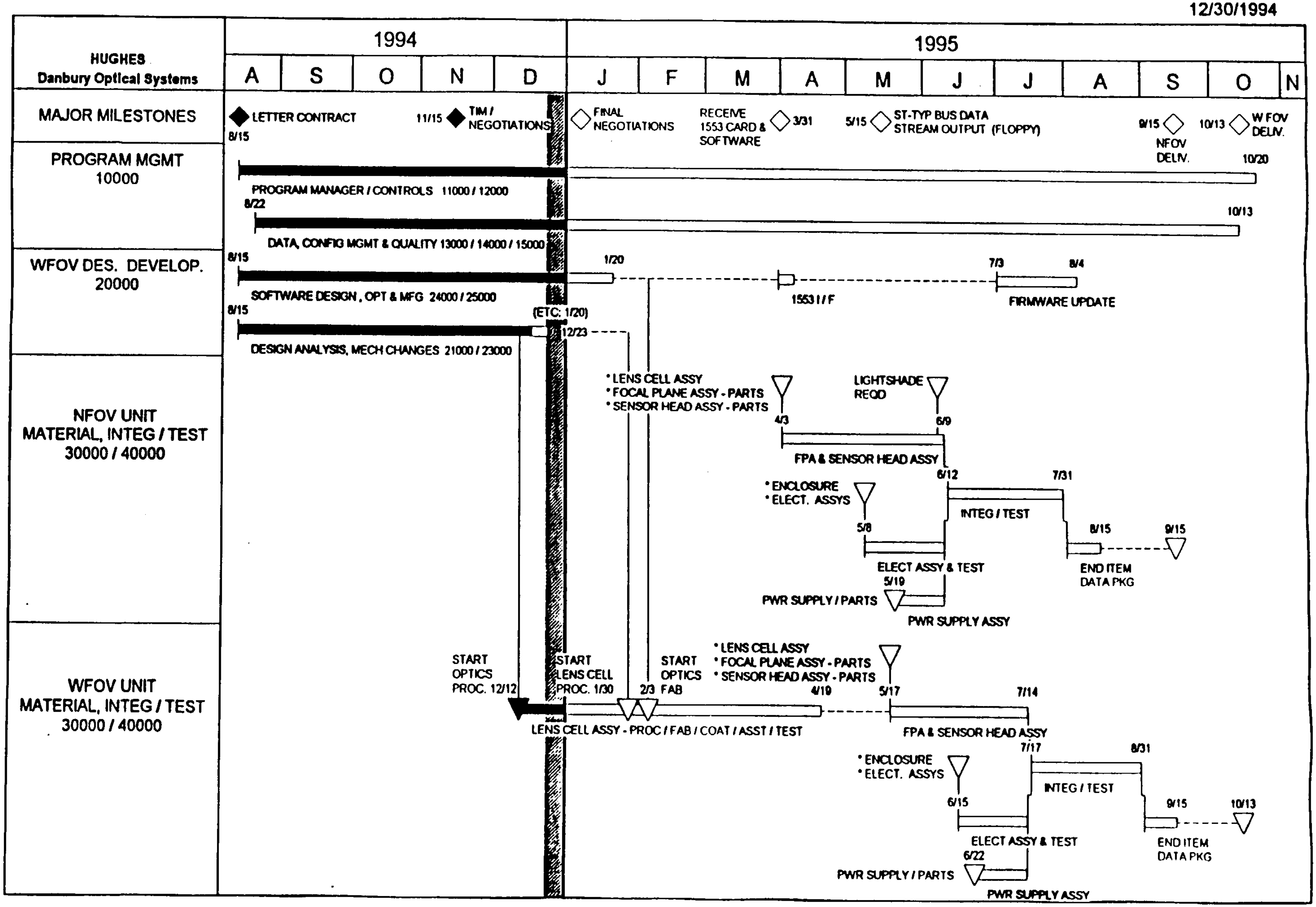
WFOV EXPERIMENT SUMMARY

- ***Purpose***: Demonstrate 3-axis all-stellar (attitude & attitude rate) determination & control by a single electro-optical sensor
- ***Design***: 20-Degree FOV variation of HD-1003 NFOV (8x8 deg) STA
  - ♦ New Lens Cell using simpler/smaller optical configuration and replacing NFOV's external Shade with internal light baffles
  - ♦ Identical to NSTA's: electronics configuration and envelope w/o Shade (7.04" x 6.2" x 4.35")
- ***Mission year #1***, data to be gathered once/day in 2-orbit bursts (TBR):
  --> Stored for ground processing and comparison with attitude and attitude rate info derived from NFOV & other S/C sensors (to evaluate all-stellar capability)
- ***Mission year #2*** goals are:
  - ♦ To provide WFOV centroid data to the ACS in order to directly validate single-tracker, all-stellar capability
  - ♦ To evaluate WFOV performance data during unique mission environmental conditions, with excessive stray light, at attitude rates > 0.3 deg/sec, and for time-related trends

TR 3STI "Lewis" S/C: WFOV/NFC SCHEDULE
NFOV & WFOV STA's

HU IES
Hughes Danbury Optical Systems, Inc.
a subsidiary

12/30/1994



1/12/95

DESIGN & PROCUREMENT STATUS

- **WFOV Design complete** --> Design Review held 11/15/94 for TRW
  - ♦ Optics detailed drawings complete
  - ♦ Final release of Lens Cell mechanical dwgs planned for 1/20
    --> Awaiting final specification of HD-1003 "blackening" process
- **Optical material** on order (ETA = 1/13)
- Starting procurement process for Lens Cell mechanical parts
  --> Plan to order by 1/30 (have approx. 1-month slack)
- HD-1003 Prototype (NFOV) on plan to complete testing end-June 1995
  - ♦ Gate Array remains critical path
  - ♦ Working some other parts issues of lesser import
- Common NFOV/WFOV parts:
  - ♦ EEE parts = Class B or better; includes upgrade screening to meet schedule
    --> Reliability No. for this "S(-)" design is 0.960 for 3-yrs and 0.936 for 5-yrs
  - ♦ All other mechanical parts on order under HD-1003 Inventory Program

--> 9/15/95 and 10/15/95 Deliveries for NFOV and WFOV remain intact

TEST APPROACH & PLANS

- 1553 I/F compatibility tests planned for April/May
- EMC/EMI requirement to be by "Similarity" to HD-1003 Prototype
- Vibration Testing unpowered at Acceptance level @ 10.26 Grms
  --> HD-1003 Prototype @ 12.2 Grms (TBR, since SSTI rqmt = 14.14 Grms)
- Thermal Cycling to be functional testing in-air @ Acceptance levels (-5C to +45C)
- Performance Testing:
  - Verify boresight & static accuracy (pitch, yaw, roll) @ -5C, +22C, +45C during one thermal-vacuum cycle at Acceptance levels; any calibration corrections vs. temperature (if req'd) to be obtained from this data
  - Verify dynamic accuracy and POA (dynamic & static) @ +22C during in-air Baseline (pre-environmental) & Final (post-environmental) Performance Tests

SSTI

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PAYLOADS & TECHNOLOGY DEMONSTRATIONS
Mag. Suspended Reaction Wheel

G. Gerson

Magnetically Suspended Reaction Wheel Assembly Summary Description

- Existing Unit, Developed On BP/AITP, Refurbished For SSTI
- Demonstrate Operation Of MSRWA In Space Environment
- Key Features Of MSRWA Compared To Current State Of Practice:
  - Lower Mass, More Compact Unit For Equivalent Function
  - Longer Life Due To Absence Of Bearing Wear/Lubrication
  - Lower Induced Disturbance (Jitter)
- Conventional Mechanical Reaction/Momentum Wheels Have A Maximum Speed Range Of 4000-6000 RPM; MSRWA Goal 15,000 RPM
- MSRWA Consists Of Dual, Two-Axis, Radially-Active Magnetic Bearings, Spin Motor & Titanium Rotor, Position & Rotation Sensors And Housing
- Drive & Control Electronics Reside In Payload Electronics Assembly

Magnetically Suspended Reaction Wheel Assembly Design Status

- Fabricated As Flight-Like Engineering Model On BP/AITP
- Functionally Tested With Breadboard Drive/Control Electronics For Over 1 Year At Speeds To Beyond 8000 RPM In Air
- SSTI Developments Include Improved Start/Restart Magnetic Bearing Control Circuit
- Still Assessing Maximum Speed Capability - May Not Achieve 15,000 RPM Due To Dynamic Range Limitations With Drive Electronics In PEA
- Design/Development Of MSRWA Complete Including New Flight-Configuration Sensor Electronics Circuit Card Mounted On MSRWA And New Enclosure For EMI/EMC & Mounting Interface

Magnetic('ly Suspended Reaction Wheel Assembly Test Approach & Plans

- Functional Performance Testing With PEA
  - Torqueing Capability
  - Torque-Speed Characteristics
  - Telemetry Interfaces With PEA
- Random Vibration Test Per EV2-099: Protoflight Level 14.14gRMS, 1 Minute Per Axis
- Thermal Vacuum Test With PEA Per EV2-099: Protoflight Level -5°C To +65°C (8 Cycles)
- EMI/EMC Testing With PEA Per EV2-099 & SR1-0125
- Final Functional Testing With PEA

Magnetically Suspended Reaction Wheel Assembly Development Schedule

• ICD Inputs (Final Draft):	Complete (12/16/94)
• Refurbishment (Replace Touchdown Bearings, Clean, Torque, Bond)	5/1/95 - 6/30/95
• Functional Testing With PEA	7/17/95 - 8/25/95
• Environmental Testing With PEA	8/28/95 - 9/22/95
• End Item Data Package	9/29/95
• MSRWA Delivery	10/13/95

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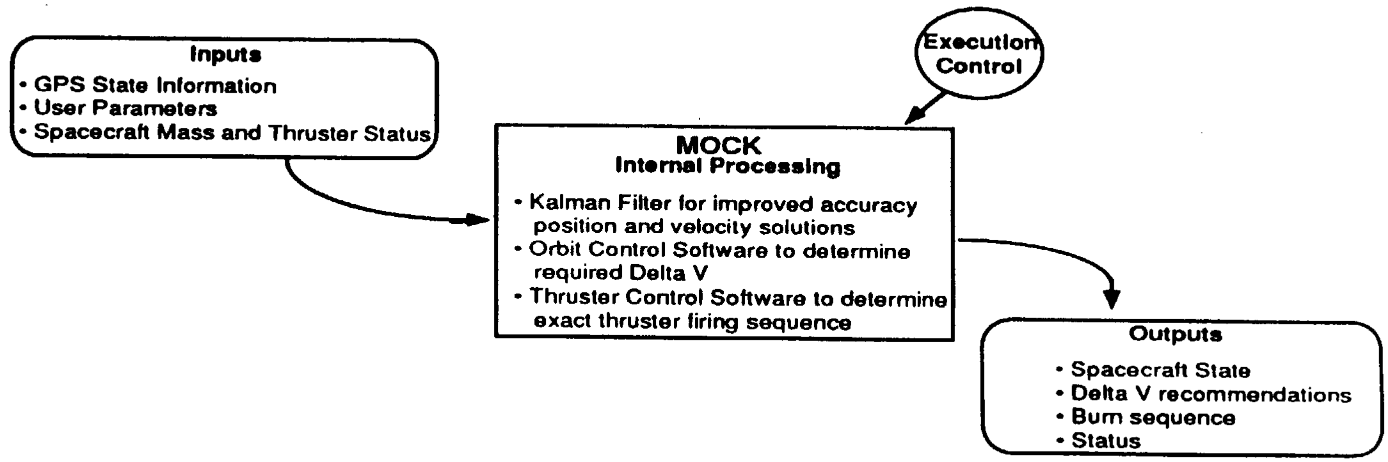
PAYLOADS & TECHNOLOGY DEMONSTRATIONS MOCK

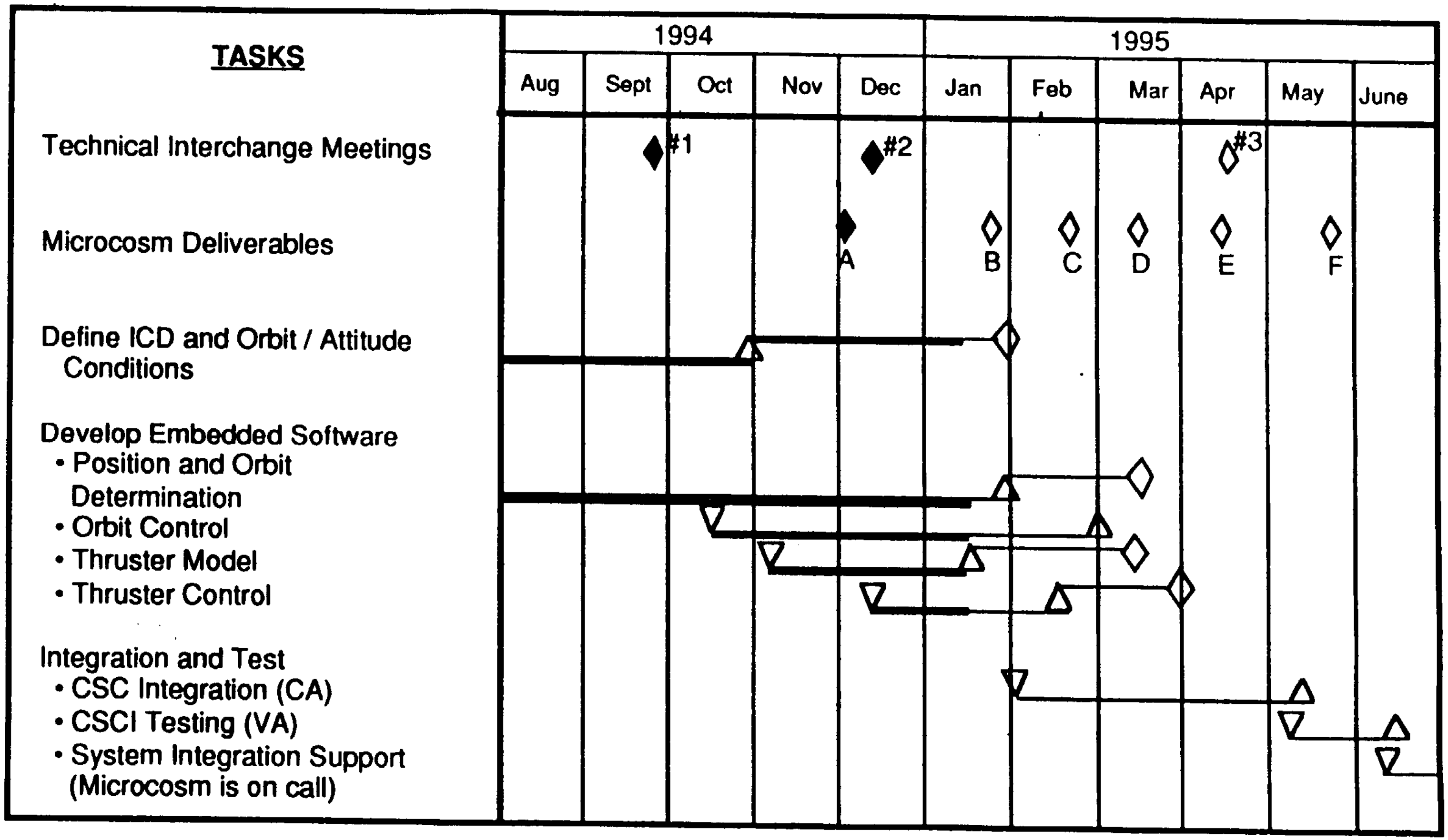
G. Gerson

MOCK SYSTEM
PAYLOAD SUMMARY DESCRIPTION



- MOCK provides Orbit Control for continuous maintenance as well as high fidelity position and velocity outputs.
  - -- MOCK Software uses GPS inputs to provide higher fidelity position and velocity outputs based on an Extended Kalman Filter.
  - -- Using this position and velocity determination, MOCK computes the required orbit maintenance burns which will maintain the prescribed orbit period and phase.

MOCK DEVELOPMENT SCHEDULE



LEGEND: Microcosm Deliverables

A ==> MOCK Software Function Description and Software Development Plan
B ==> Update of MOCK Software Function Description
C ==> Stubs and Headers for Early Integration
D ==> Test Methodology
E ==> Revised Stubs and Headers
F ==> MOCK Software for Integration

MOCK SOFTWARE
DESIGN/PERFORMANCE VERIFICATION

- Design Requirements:
  - -- Size: Less than 32K words with a goal of 24K words.
    - ° Verification of size requirement compliance will be performed through inspection of load map (generated by VxWorks in Chantilly) as allocated on target processor.
  - -- Throughput: MOCK Software must operate in less than 0.8 second while being called every 16 seconds. MOCK Software will be suspended by the Kernel during operations.
    - ° Verification of throughput requirement compliance will be performed through execution at Chantilly on target hardware during integration testing. Early delivery of stubs and headers will provide metrics.

- Performance Requirements:
  - -- Position and Velocity outputs with higher fidelity than input GPS data. Kalman Filter will provide approximately a factor of 5 improvement of Position and Velocity outputs.
    - ° Verification through collection of MOCK generated on-orbit data and ground-based comparison with GPS raw outputs, position of ground control points extracted from HSI data and tracking data.
  - -- Orbit Control and Maintenance in agreement with ground-based recommendation from TRW analysts.
    - ° Verification through collection of MOCK generated data on-orbit and detailed analysis and comparison with ground-based analysts.

MOCK SOFTWARE
STATUS OF DESIGN AND PROCUREMENT

- Design Status:
  - -- Top-Level Design presented at 12/94 TIM. Software packages, interfaces, and functional flow diagrams have been defined.
  - -- Interface Definitions have been revised, presented by Microcosm at the 12/94 TIM, and agreed to (in principle).
    - ° MOCK will run at 16 second intervals. MOCK software will be called without any parameters and will handle internal scheduling.
    - ° MOCK Inputs and Outputs will be via statically allocated buffers.
  - -- Several outstanding ICD issues to be clarified by TRW:
    - ° Exact definition of GPS inputs: units and availability of FOM discretes.
    - ° Interfaces to thrusters and if thruster model and/or interface software will exist from TRW for use by Microcosm.
    - ° Availability and performance of Built-in-Functions (BIFs) provided either by hardware or kernel software.

- Procurement Status:
  - -- Final Contract between Microcosm and TRW expected week of 9 January 1995.
  - -- Microcosm is operating under original letter contract. Letter contract has been extended to continue effort until final contract is in place.

MOCK SOFTWARE
TEST APPROACH AND PLANS

- MOCK Software is based on COTS software, providing complete baseline for testing both at Microcosm and at TRW in Chantilly.
  - -- Kalman Filter based on MANS operations during TAOS Step 0 mission.
  - -- Orbit Control Kit based on Microcosm SBIR and ground-based prototyping of algorithms
  - -- Performance of MOCK Software components have been baselined. Integration testing will have concrete expected results.
- Dynamic Testing of MOCK Software at Microcosm is based on COTS ground-based simulation - Microcosm Ground Based Simulator (GBS).
  - -- MOCK enhancements include addition of selective availability modeling in GPS model.
  - -- Ada shell provided for SA model as well as MOCK "C" software for seamless execution.
- Testing of MOCK Software in target processor will be performed at Chantilly.
  - -- Dynamic inputs based on GBS GPS modeling will be provided by Microcosm for testing in Chantilly.
  - -- MOCK performance on target hardware will be evaluated incrementally through early delivery of stubs and headers and during CSC integration testing in Chantilly.

PAYLOADS & TECHNOLOGY DEMONSTRATIONS
Enhanced ACS

P. Maghami

TECHNOLOGY DEMONSTRATION DESCRIPTION

- Develop and implement multi-input/multi-output (MIMO) control designs and algorithms for the Lewis Spacecraft
- The experiment would be conducted in second or third year of operation
- LaRC develops a software module to implement the MIMO ACS design
- The enhanced ACS would be implemented as an additional module within the flight software
- LaRC designs and evaluates advanced MIMO control designs: with TRW participation
- Plans are to integrate the enhanced ACS software before launch and upload each ACS design data
- TRW would provide integration and uploading capability

DEVELOPMENT SCHEDULE

Activity	Delivery/Completion date
Develop and deliver a FORTRAN version of the MIMO routine (for simulation purposes)	Jan 95
Develop an LaRC simulation of LEWIS	Feb 95
Develop and deliver the flight version of the MIMO routine for simulation and implementation (in C language)	Mar 95
Design, evaluate, and deliver three MIMO controllers (for verification purposes)	Mar 95
Continue design and evaluation of candidate MIMO control laws	Apr 96
Develop and submit flight test plan	Dec 96
Evaluate and analyze flight test results	after Jul 97

CURRENT STATUS

- Lewis structural model received [Dec 94]
- Current baseline normal mode module received [Jan 95]
- Completed a FORTRAN version of the MIMO module and delivered to TRW [Jan 95]
- Developing a MATLAB simulation of LEWIS with available information to evaluate:
- — Baseline normal mode controller

  — MIMO controllers
- Developing the flight version of the MIMO module (in C language)
- Designing three MIMO controllers to be used for verification of the MIMO module

TEST/VERIFICATION APPROACH

- The MIMO module would be as self-contained as possible to minimize implementation and verification efforts
- A FORTRAN version and a flight C version would be developed
- Three MIMO controllers will be used for verification of the module:
  - — A MIMO equivalent to the baseline normal mode: may be used as a back up to baseline normal mode
  - — An Enhanced MIMO controller
  - — A destabilizing MIMO controller
- These controllers would test the MIMO module including the safety hooks
- These control designs would be verified through:
  - — LaRC MATLAB simulation
  - — TRW FORTRAN and C simulations
- Future control designs would be verified through LaRC MATLAB simulation

PAYLOADS & TECHNOLOGY DEMONSTRATIONS
On-Orbit ID

K. Elliott

Langley

On-Orbit Identification

SSTI TRW

Task Description:

On-Orbit ID is an analysis task with the goal of qualifying the spacecraft's dynamic performance from on-orbit telemetry data. (Characterization of SA dynamics and qualification of jitter environment.)

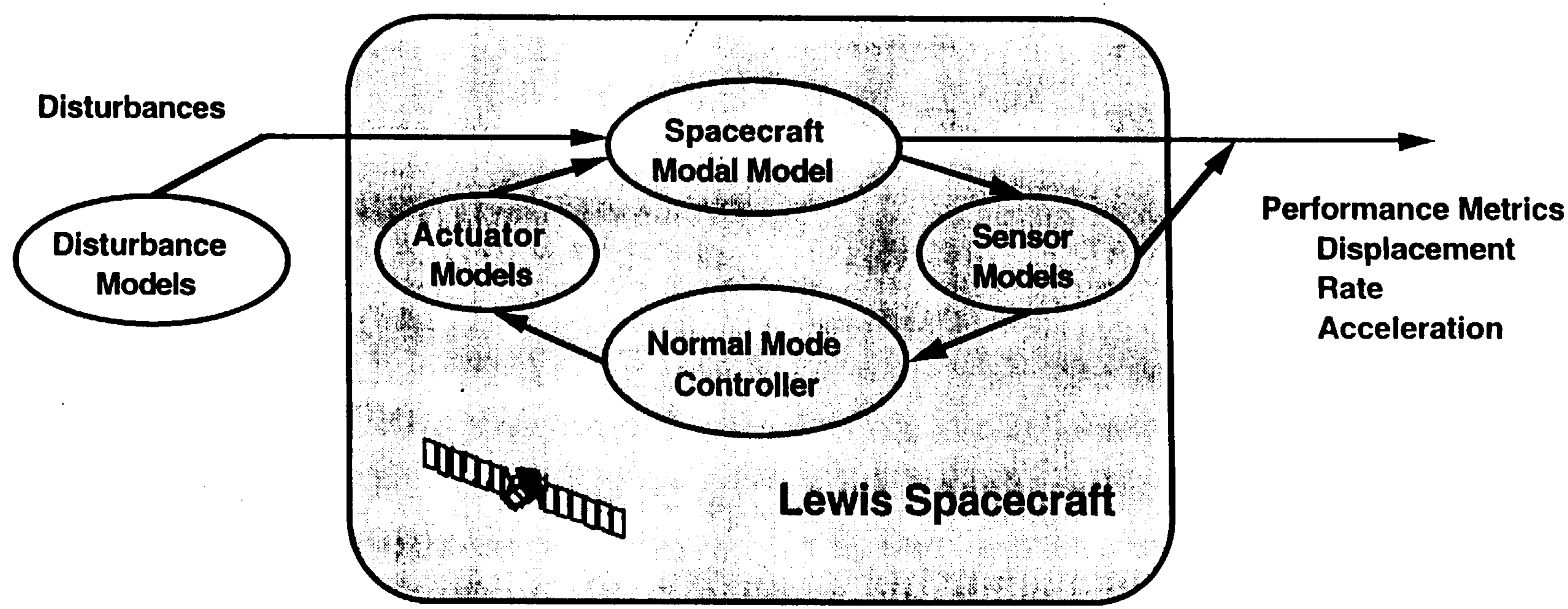
Status/Schedule

Task	Schedule	Status
Assessment of SC resources and development of test approaches	11/30/94	Ongoing Performing SC simulations
Final flight test plans	01/31/96	01/31/96
Flight tests	07/01/97	07/01/97

KBE 1/95

Langley

Spacecraft Simulations



KBE 1/95

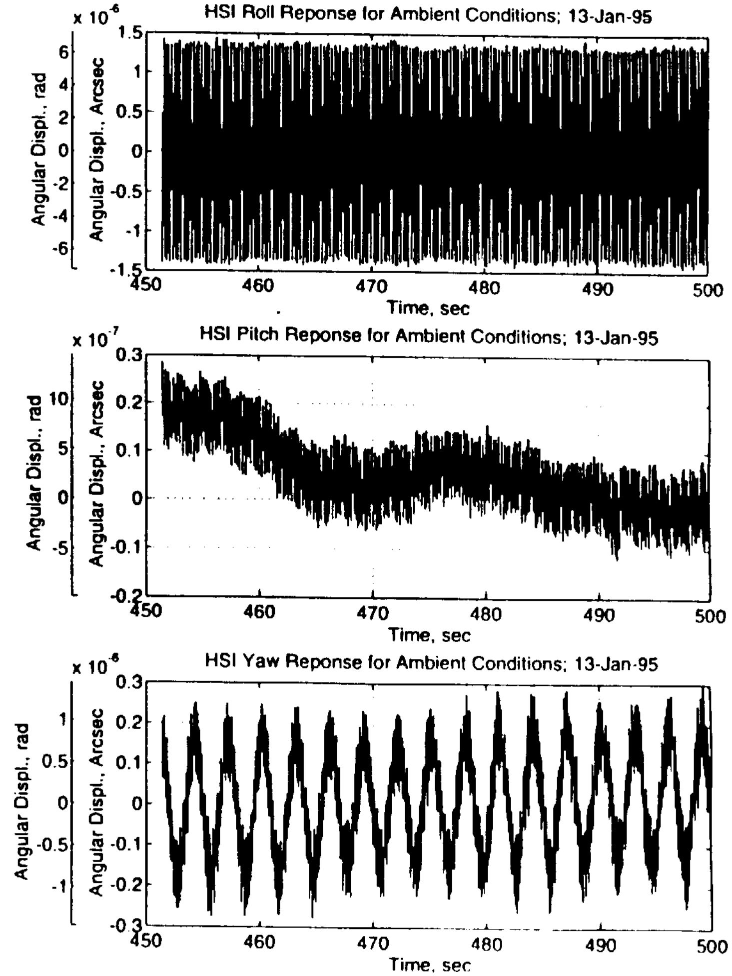
Spacecraft Simulation Result

Typical PLATSIM Result

- 3-axis response at HSI
- Model dynamics up to 275Hz (350 modes)
- Normal mode control (LaRC derived)
- Nominal ambient disturbances :
  - 4 reaction wheels (run at bias)
  - HSI cryo-cooler
  - LIESA cryo-cooler
- Jitter values:

Jitter, arcsec

Response Location	Window Size, sec 0.1	1.0	10.0
HSI Roll	2.91	3.03	3.03
HSI Pitch	0.83	0.86	1.10
HSI Yaw	1.36	1.75	1.84



KBE 1/95

PAYLOADS & TECHNOLOGY DEMONSTRATIONS
PEA/OPA/Cryocoolers

G. Gerson

SSTI

Summary Description of PEA

- Drives four loads:
  - MSRW
  - HSI cryo cooler
  - LEISA cryo cooler
  - LEISA OPS
- Receives commands and telemetry via 1553.
- Receives 28V spacecraft bus power.
- Has primary and redundant secondary power.
- Processes 6 HSI temperatures for telemetry.
- Presently adding the APEX RH32 processor experiment in a spare PEA slot.
- 4.1 X 7.3 X 7.3 inches, 8 pounds, and 28 Watts before adding APEX.
- 1900 electrical parts with 67 part types.

PEA Design and Procurement Status

- All PEA electrical design is final and the flight printed circuit boards are being designed
- All parts are on order with no crisis situations
  - In general the parts procurement is about a month behind schedule but only a few parts are posing lead time problems as a result
  - Alternatives are still easy to implement since the product engineering is not complete
- The addition of APEX has no cost or schedule impacts to SSTI program
- MSRW speed is limited to 8000 rpm with no further resources to improve the performance

SSTI

PEA Test Approach and Plans

- Will test the PEA as a unit starting in early August 1995 for a mid October delivery.
- The loads will be:
  - LEISA OPA flight unit and dummy loads for the cooler
  - HSI Use the SSTI cryo cooler brassboard
  - MSRW Use the flight MSRW
- The PEA and its loads will be in the thermal vacuum chamber together. CMD and TLM is via the 1553 interface to the external test set.
- The unit will be unpowered during vibration testing.
- Unit will undergo EMC testing in a chamber.
- PEA Test procedures will be written in March.
- HSI engineering model cryo cooler drive electronics delivered in July.

Optical Pointing Assembly Summary Description

SSTI

- Existing Unit, Developed On BP/AITP, Refurbished For SSTI
- Provide Wide, Agile Field Of Regard (FOR) For LEISA
- Extends LEISA FOR To:

  +12°/- 28° Elevation (Spacecraft Pitch)

  174° Azimuth (Spacecraft Roll)
- Allows FOR To Be Changed Within 40 mS Over Wide Range
  - Minimum Step Size 33.5 microradians
  - Maximum Step Size 7.8°
- Provide High Position Resolution & Accuracy
  - Position Resolution 12 microradians
  - Position Accuracy/Knowledge < 150 microradians
- OPA Consists Of Azimuth & Elevation Motors, Bearings, Cable Wraps, Position Sensors And Housings, Plus Flat Mirror
- Drive & Control Electronics Reside In Payload Electronics Assembly

Optical Pointing Assembly Design Status

SSTI

- Fabricated As Flight-Like Engineering Model On BP/AITP
- Modified For Flight On AITP/ESF
- Performance Tested On AITP To Verify:
  - Initial Alignment & Hardstop Positions
  - Noise (Crosstalk)
  - Scale Factor
  - Steady State Jitter
  - Step Resolution & Settling
- Temperature Cycled From 2°C To 49°C To Verify Mirror Stability, Alignment Insensitivity & Step Performance
- Random Vibration Exposure (Unpowered/Uncaged) At ~1/2 SSTI Protoflight Levels (6.77 gRMS In-Plane/ 8.4 gRMS Out-Of-Plane)
- Design/Development Of OPA Complete

SSTI

Optical Pointing Assembly Test Approach & Plans

- Functional Performance Testing With OPS Test Set
  - FOR (Azimuth & Elevation Range/Limits)
  - Step Size Min./Max. Limits
  - Resolution, Accuracy
- Functional Compatibility Testing With PEA (Primarily Interfaces)
- Random Vibration Test Per EV2-099: Acceptance 10gRMS, 1 Minute Per Axis
- Thermal Vacuum Test With PEA Per EV2-099: Acceptance LImits -24°C To +61°C (8 Cycles)
- EMI/EMC Testing With PEA Per EV2-099 & SR1-0125
- Final Functional Testing With OPS Test Set

Optical Pointing Assembly Development Schedule

• ICD Inputs:	Complete
• Refurbishment (Torqueing, Bonding)	4/3/95 - 5/26/95
• Functional Testing (OPS Test Set)	6/5/95 - 7/28/95
• Functional Testing With PEA	8/1/95 - 8/25/95
• Environmental Testing With PEA	8/28/95 - 9/22/95
• End Item Data Package	9/29/95
• OPA Delivery	10/13/95

Pulse Tube Cryocooler Mechanical Assembly

LEISA deliverables

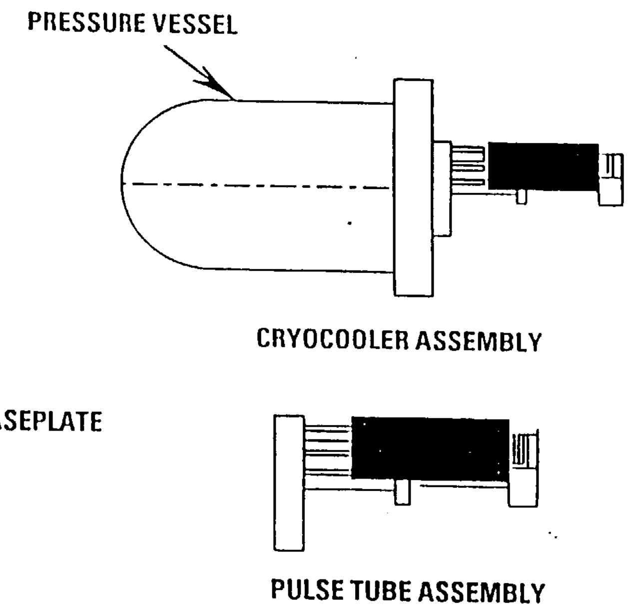
- TRW4-PTC
    - Built for Brilliant Pebbles, transferred as is to SSTI
- Ground Support Equipment + User's Manual
    - Built for Air Force Phillips Lab, on loan to SSTI

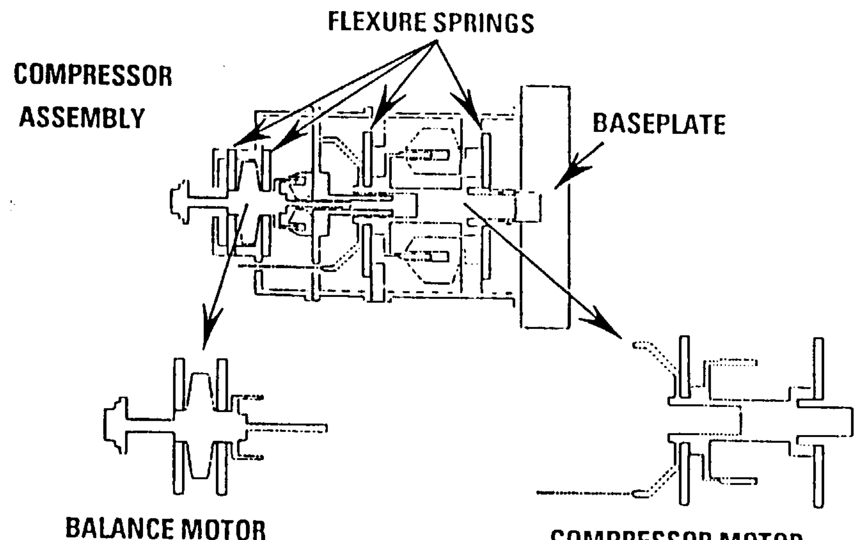
HSI deliverables

- One new pulse tube cryocooler
- Identical cooling mechanism as TRW4-PTC, minor case differences

Major Components

- COMPRESSOR ASSEMBLY
- PULSE TUBE ASSEMBLY
- PRESSURE VESSEL
- BASEPLATE
- FLEXURE SPRINGS





SSTI

Requirements and Capabilities

Specification	Requirement: LEISA	Requirement: HSI	Capability*
Load Power	≤0.4 W	≤1.2 W	1.2 W**
Cold Head Temperature	78K***	110K***	78K/0.4W @ <20W 110K/1.2W @ 18W
Operating Temperature (cooler base plate)	+2°C to +25°C	N/A	+2°C to +47°C
Design Life	3 years	5 years	7 years
Mass	2.0 kg	2.0 kg	2.0 kg

* Capabilities measured on prior units.
** For 18W cooler input power, 25°C reject temperature.
*** Derived from FPA temperatures of 83±5K for LEISA, 115±1K for HSI.

Cryocooler Status

LEISA

- Cooler undergoing performance tests for system thermal design
- GSE and User's Manual (draft) ready
- Anticipate shipping to GSFC by end of January

HSI

- Purchase Orders and Requisitions issued
- Hardware procurement & fabrication ~80% complete
- Manufacturing Shop Orders complete
- On schedule

SSTI

Cryocooler Test Approach

TRW

LEISA

TRW4-PTC cooler has been tested for performance at ambient temperature

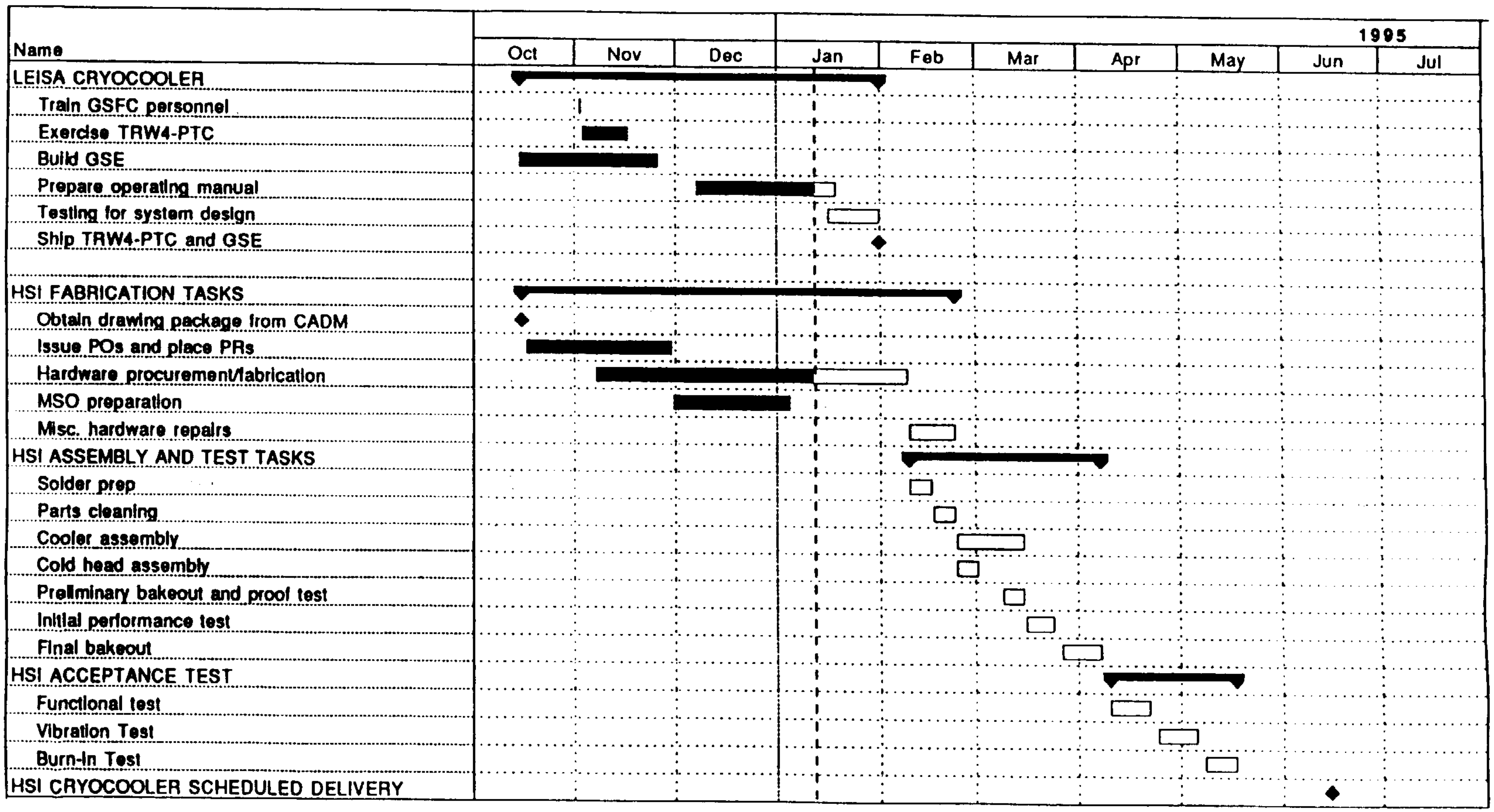
Acceptance testing to be performed with complete instrument

The design has been qualified to SSTI levels

HSI

Will undergo testing per EV2-099 as part of HSI

SSTI Cryocooler Schedule



PAYLOADS & TECHNOLOGY DEMONSTRATIONS
New Experiments

D. Conte

PV Regulator Kit (PRKE)
SSTI Experiment Review

Objectives

- Demonstrate the operation of key components of a low cost, high efficiency, modular, fault tolerant electric power management and control system targeted for inexpensive small sattellites.
- Demonstrate the use of commercial off the shelf power electronic parts for small sattellites electric power systems.
- Investigate the long term operation of a Series Connected Boost Unit (SCBU) built using commercial parts in the LEO space environment.

Lewis Research Center

General Description

- Hardware Description
  - Series Connected Boost Unit
    - Based on the Interpoint MFL2812S Power Supply
  - Experiment Test Electronics
    - Sundstrands AVX-30 1553B general purpose data acquisition module
    - Electronic Recirculator
      - Based on the Vicor VI-224-CW Power Supply
- Functional Description
  - The series connected booster unit (SCBU) provides battery current control and bus voltage regulation.
  - The electronic recirculator (ERC) acts as a dummy load to the SCBU.

Requirements

- Power
  - PRKE requires a 28VDC input rated at 40 watts max.
- Thermal
  - Thermal dissipation shall be no more than 40 watts.
- Telemetry
  - Table 1.7.1-1 of the ICD contains the telemetry requirements for PRKE. Four data items and a discrete status bit are the only requirements.
  - Data Storage requirements shall not exceed 300 bytes per operating experiment cycle.
- Commands
  - Table 1.6-1 of the ICD contains the required PRKE commands.

Spacecraft Interfaces

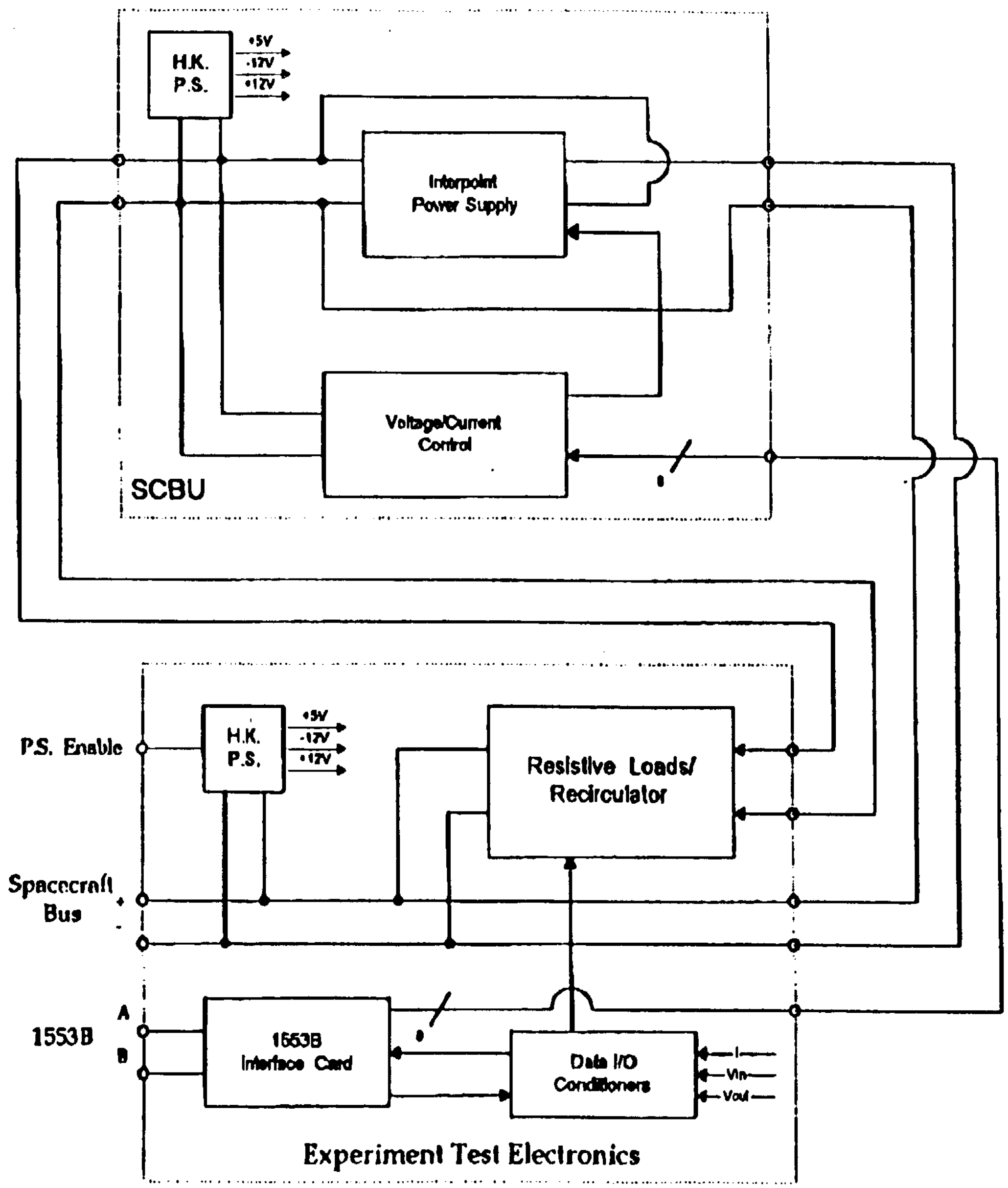
- Mechanical
  - Size
    - The PRKE box is 4.9" x 3" x 9.35"
  - Mass
    - PRKE NTE mass is 1.5 kg (current estimate is 1.36 kg)
- Electrical
  - Inputs
    - All digital data transfer from and to PRKE is accomplished via 1553B bus
    - A bi-level input is required to turn the 1553B power supply on/off.
  - Outputs
    - All digital data transfer from and to PRKE is accomplished via 1553B bus
- Thermal
  - Operating temperature : TBD
  - Mounting plate temperature limits -TBD to +TBD
  - Power dissipation : 40 watts max

Lewis Research Center

Status

- Design Status
  - Electrical Design Completed
  - Data Interface Design Completed
  - Mechanical/Packaging preliminary design completed
  - Breadboard of experiment operational
- Documentation
  - ICD - 80%
  - Environmental Test Plan - Draft in works
  - Design Package - In works
  - Spacecraft Integration and Test Document - TBD
- Major Milestones
  - ICD Complete - 12/6/94
  - Design Complete - 12/30/94
  - Testing Complete - 5/19/95
  - Deliver Flight Unit - 10/15/95

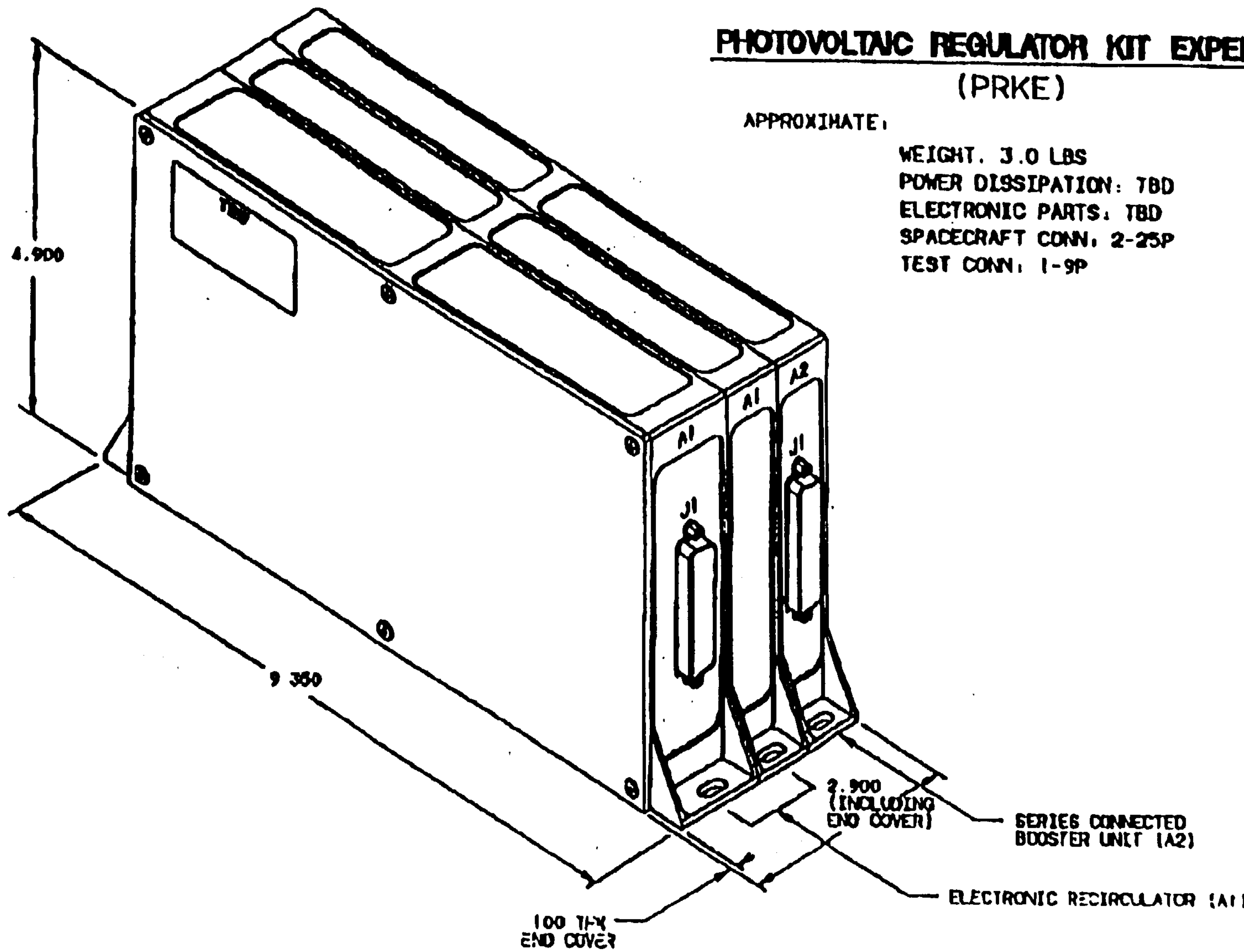
Figure 1.2.3-1 PV Regulator Kit SS. periment Block Diagram



PHOTOVOLTAIC REGULATOR KIT EXPERIMENT
(PRKE)

APPROXIMATE:

WEIGHT. 3.0 LBS
POWER DISSIPATION: TBD
ELECTRONIC PARTS: TBD
SPACECRAFT CONN: 2-25P
TEST CONN: 1-9P



SSTI

Advanced Packaging Experiment

- The Advanced Packaging Experiment (APEx) demonstrates new commercial packaging technology for flight application that will substantially reduce size, weight, power, and development cost
- Comprises high performance processor (RH32), cache memory, 2 Mbyte SRAM, 0.5 Mbyte EEPROM, memory management and programmable interface in a single 2” x 4” multichip module (MCM)
- Joint effort by Jet Propulsion Laboratory (JPL) and TRW
- Fits on a single board within Payload Electronics Assembly (PEA)
- Characteristics:
  - Mass: 0.6 kg
  - Power: 3.0 W nominal, 5.0 W maximum

Phillips Laboratory Experiment (PLEX)

- Demonstrate multichip module (MCM) compact packaging technology for reduction of size, weight, power, and cost of flight electronics
- Experiment comprises an RAD6000 processor and associated memory
- Fits on a single board within Payload Electronics Assembly (PEA)
- Characteristics:
  - Size: One-sided 4" x 6" board
  - Mass: $\leq$ 0.6 kg
  - Power: $\leq$ 5.0 watts

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TRW

PAYLOADS & TECHNOLOGY DEMONSTRATIONS
Summary

D. Conte

PLANS

- Complete ICD Signoff Process
  - Institute Formal Revision/Change Process
  - Maintain Revision/Change Paperwork

- Resolve Open Items

- Develop Experiment Integration And Test Plans/Procedures
  - Receiving Inspection and Pre-Integration
  - Interface Verification
    - Functional
    - Commands
    - Telemetry Response
  - Aliveness
  - Requirements/State For Spacecraft-Level Tests

- Review On-Orbit Plans (With Operations Manager)
  - On-Orbit Check-out
  - Routine Operation Sequences

SPACECRAFT BUS
Overview

K. Biber

SPACECRAFT BUS
Structure & Mechanisms

A. Barrett

Outine

- Items included in structure subsystem
- Status: design development, hardware acquisition, fabrication
- Bus and payload modules structure description
- Solar array structure and mechanisms description
- Requirements/capabilities/verification approach summary
- Test approach and plans
- Schedule

SSTI

Structure Subsystem Scope of Work

TRW

- Flight Hardware Deliverables
  - Structure, Bus and Payload Modules
    - Battery/Propulsion Module (BPM)
    - Avionics Module (AM)
    - Payload Module (PM),
    - Equipment Brackets: GPS Antenna, Earth Sensor, etc.
  - Payload Housings and Interface Brackets
    - Leisa Enclosure
    - Interface Flexures: Leisa, UCB, HSI
  - Solar Array Structural/Mechanical Assembly
    - Substrate Panels/Hinges and Yoke
    - Stowed Restraint Mechanism
    - Release Devices (G&H)

- Non-Flight Hardware to Be Designed and Fabricated
  - Adapter Ring, Test and Shipping, (Attached to LV I/F Ring)
  - Hoist Beam with cables and hooks (three-point attachment on PM)
  - Fixture: Solar Array Vibration and Deployment Test
  - Proof Loading Fixtures: BPM, AM-PM
  - Mass Simulators of Satellite Equipment for Dynamic Test of Structural Assembly

SSTI

Structure Subsystem Scope of Work
(Continued)

TRW

- Design and Analysis Engineering Outputs
  - Layouts and detailed drawings of all hardware to be fabricated.
  - Load cycle models and results evaluation.
  - Analysis support to HSI structure development.
  - On-orbit model for jitter analysis.
  - Analysis report verifying structural and functional adequacy of all hardware.

- Test Verification Activities
  - Development tests of critical joints.
  - Static proof test of structure modules
  - Modal verification test of structural assembly (with mass simulators)
  - Vibration test and deployment test of solar array assembly (with mass simulators of electrical components).

- Structural Interface Coordination Activities
  - Identify need dates for finalizing interfaces with equipment attached to structure.
  - Coordinate insulation and contamination control inputs to assure needed structure features are included.
  - Hold regular coordination meetings to resolve structural interface issues.

Major Configuration "Drivers"

i.e.: Critical Requirements Governing the Basic Structural Configuration

1. Accommodate all payload items and bus equipment while fitting within the Pegasus fairing envelope.

2. Provide capability to scale up sizes of mounting panels and radiator surfaces (to utilize available volume in Taurus or LLV fairing) without changing basic configuration or load paths.

3. Provide modularity for parallel integration of: battery/propulsion module, avionics module, and payload module to minimize integration span time.

4. Maximize payload mass fraction, (i.e.: minimize structural mass fraction). This requires use of advanced composite materials.

5. Provide adequate thermal conductivity between heat dissipating equipment and radiator surfaces.

6. Provide adequate strength and stiffness in primary load path for Pegasus minimum frequency requirement and load factors at the Pegasus maximum weight or for the corresponding LLV parameters. (Pegasus is critical.)

SSTI

Key Structural Configuration Features

TRW

1. Thermal/mechanical isolation of payload instruments
    - HSI, LEISA, UCB instrument assemblies designed as stand-alone items.
    - Each instrument assembly has own thermal radiator.
    - Low-conductivity flexures, (T300 GFRP) mount each instrument assembly to R/F spacecraft structure.
        - Unconstrained thermal expansion and conduction
        - Thermal conductive isolation
    - Mechanical/thermal isolation facilitates testing instruments prior to satellite integration.
2. Modularity
    - All three structure modules, BPM, AM PM, designed for modular integration
        - Bolted interfaces
        - Bolts accessible after integration of equipment
        - AM/BPM joint accessible from BPM
        - AM/PM joint accessible from PM
    - Three module parallel integration of satellite possible.
    - Mechanical interface ring (AM/PM) and fittings (AM-PM) serve as electrical ground connection between modules.
3. Battery panel baseline accessible for installation and removal prior to integration with launch vehicle.

Key Structural Configuration Features
(Cont'd.)

4. Central Cylinder Primary Structure Load Path
   To facilitate modularity, adaptability and
   provide volume to store propellant tank.

5. GFRP composite construction to minimize weight, with variety of reinforcing fibers utilized.

6. Dimpled aluminum foil for interface conductance at equipment-panel and radiator-panel interfaces.

7. Belleville washers to maintain adequate contact pressure on dimpled for thermal interfaces during mission design life.

8. Strain energy hinges for solar array.

9. Mechanical attachment of solar array hinges to panel to avoid high stress in bond of aluminum hinge to GFRP panel due to CTE mismatch.

SSTI

Status: Design, Hardware Acquisition

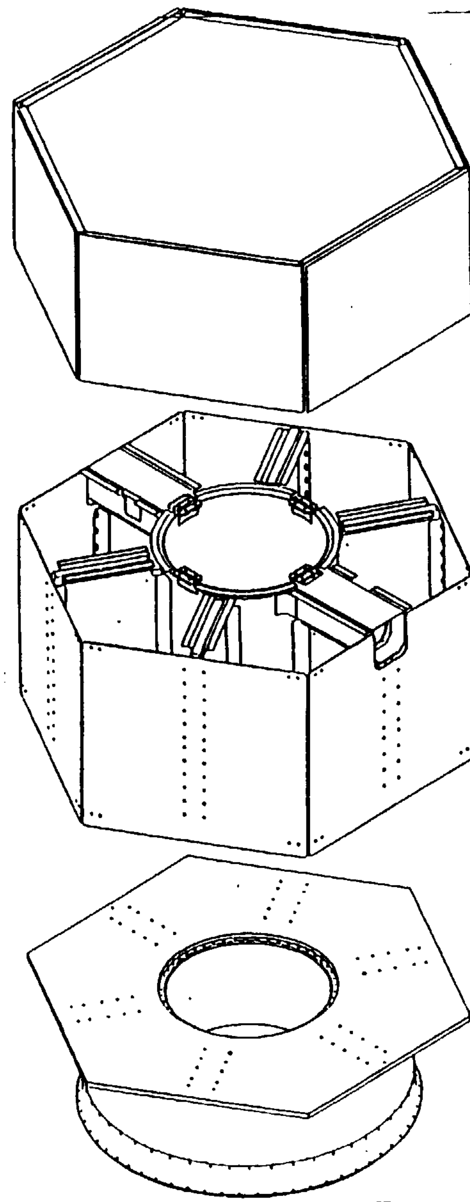
- Solar Array
  - Reduced number of panels from 6 per wing to 4 per wing (increased panel size to provide adequate area).
  - Designed yoke to accommodate all electrical power experiments.
  - Baselined a restraint/release system which minimizes number of parts, development time and fabrication time.
  - Held design review of updated design.
  - Hinge stiffness development test articles in fabrication.
- Bus and Payload Modules
  - Have released 19 drawings (1/3 of total).
  - Have received all material.
  - Completed lay-up of BPM/AM central cylinder.

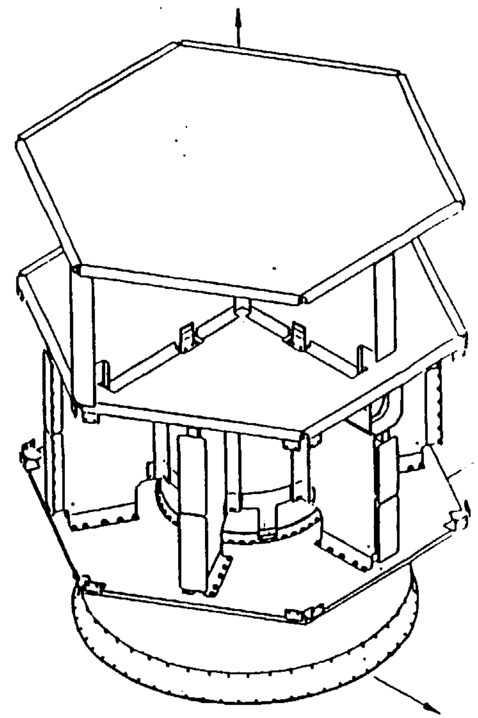
Payload and Bus. Modules

PM

AM

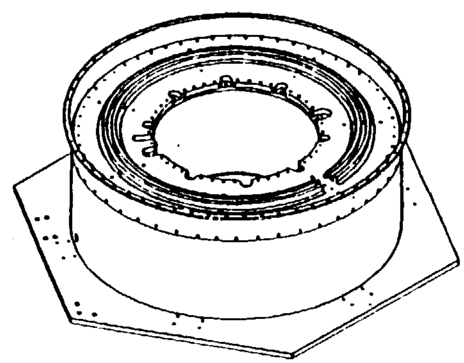
BPM



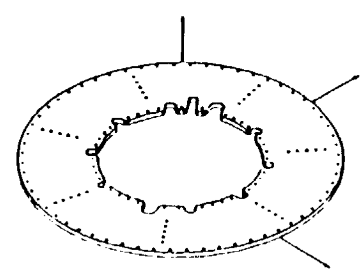


3 - Module Assembly without radiator panels

BPM

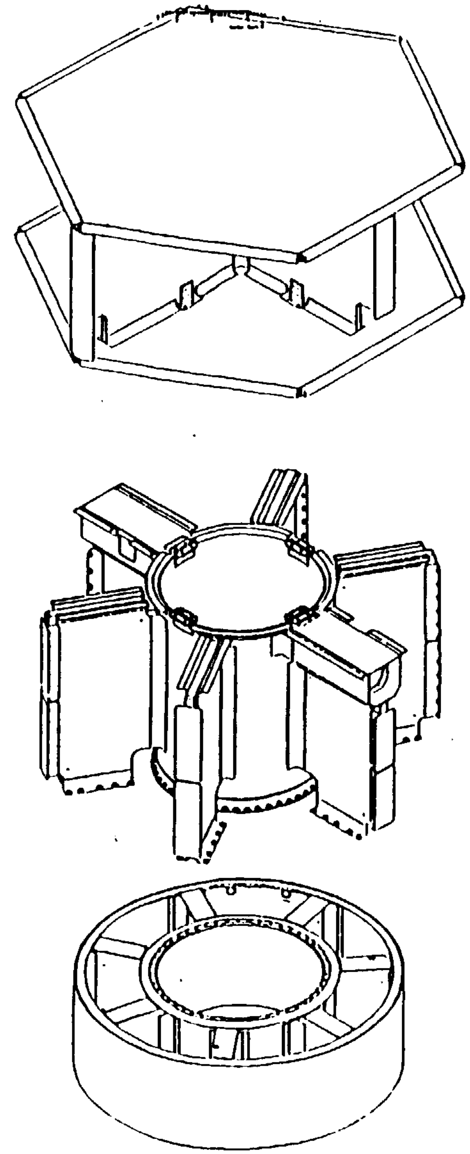


View showing heat pipes on battery panel

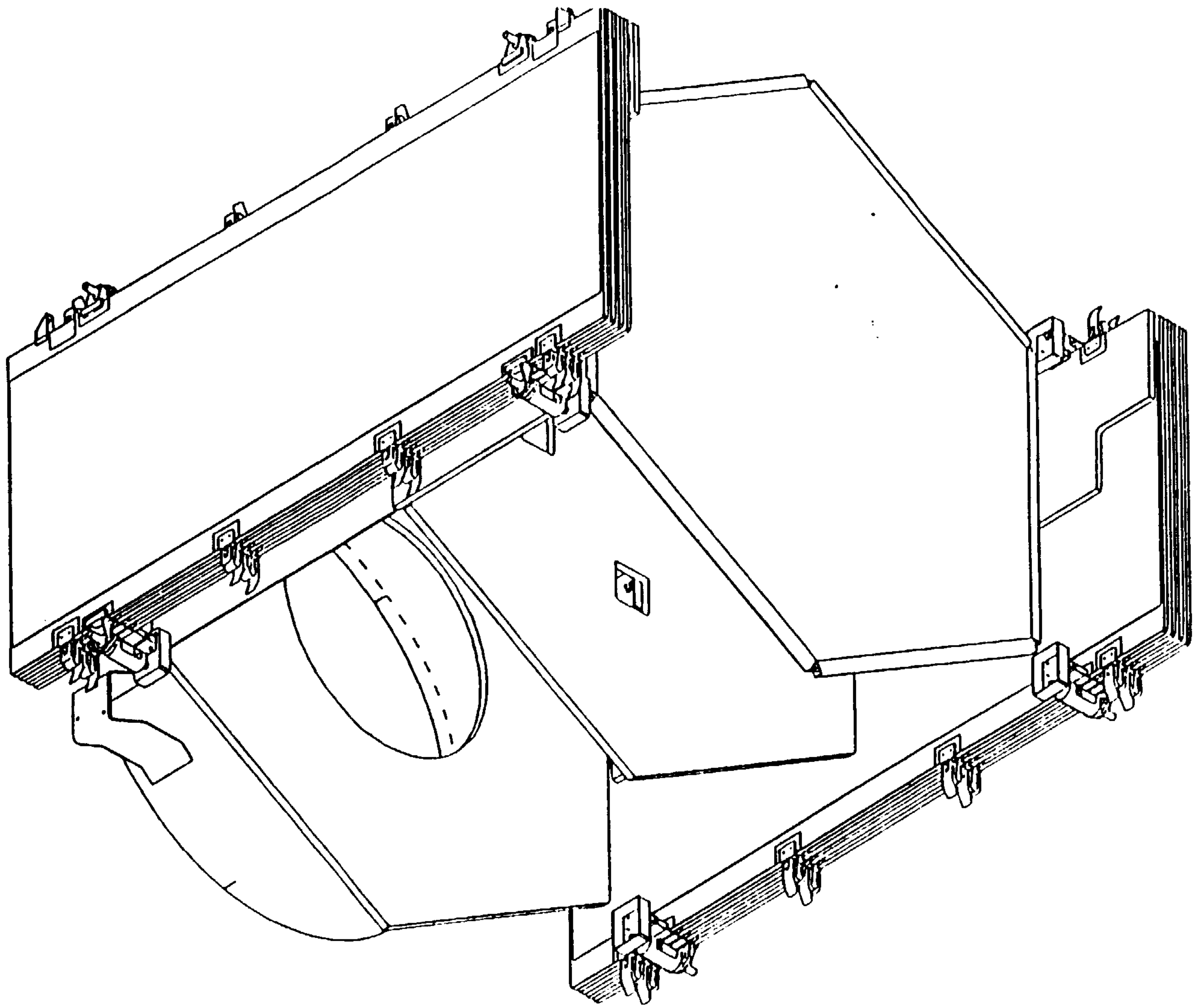


Battery Panel

Payload and Bus. Modules

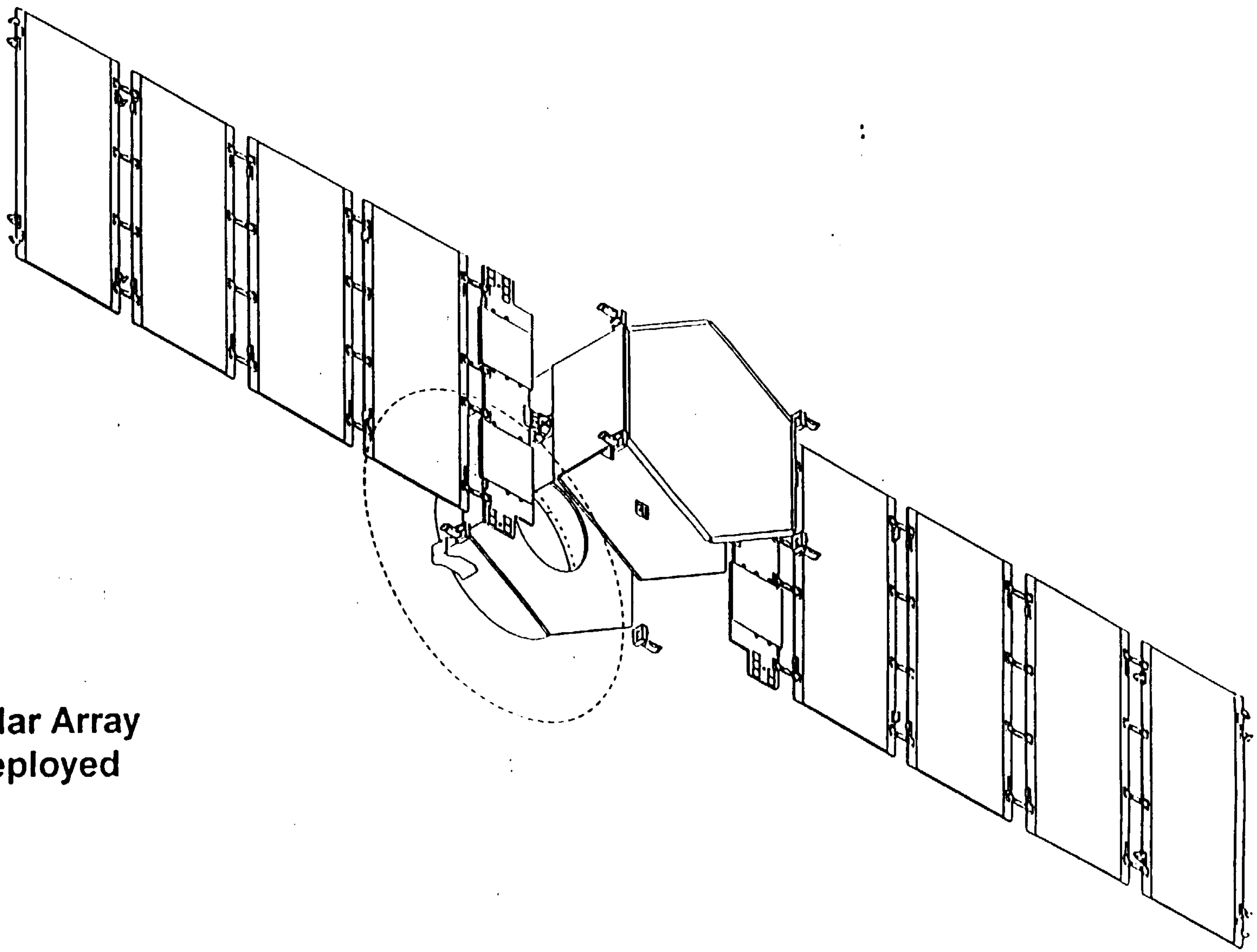


SSTI



Solar Array Stowed

6



Solar Array
Deployed

SSTI

Design Key Features

TRW

- Four Panels Plus Yoke Each Wing
  - Bus solar cells on four panels
  - Solar power experiments on yoke

- Substrate Panels
  - Similar to STEP
  - M60J GFRP facesheets, 3 plies X .0025
  - 3/8 AL. honeycomb core: 1.6 pcf basic, 3.1 pcf at hinges
  - Secondary doublers plus bushings at hinges

- Hinges
  - Strain energy (carpenter tape) hinges
  - Bolted Attachment
    - = Eliminates risk of bond failure due to thermal stress
    - = Each hinge sub-assembly, consisting of two clevis fittings plus carpenter tape is replaceable.
  - Fixturing used to control hole locations to permit interchanageability of hinges
  - Liquid shims with parting agent used to fill gap between panel and hinge clevis
  - "Semi-Stops" absorb deployment energy

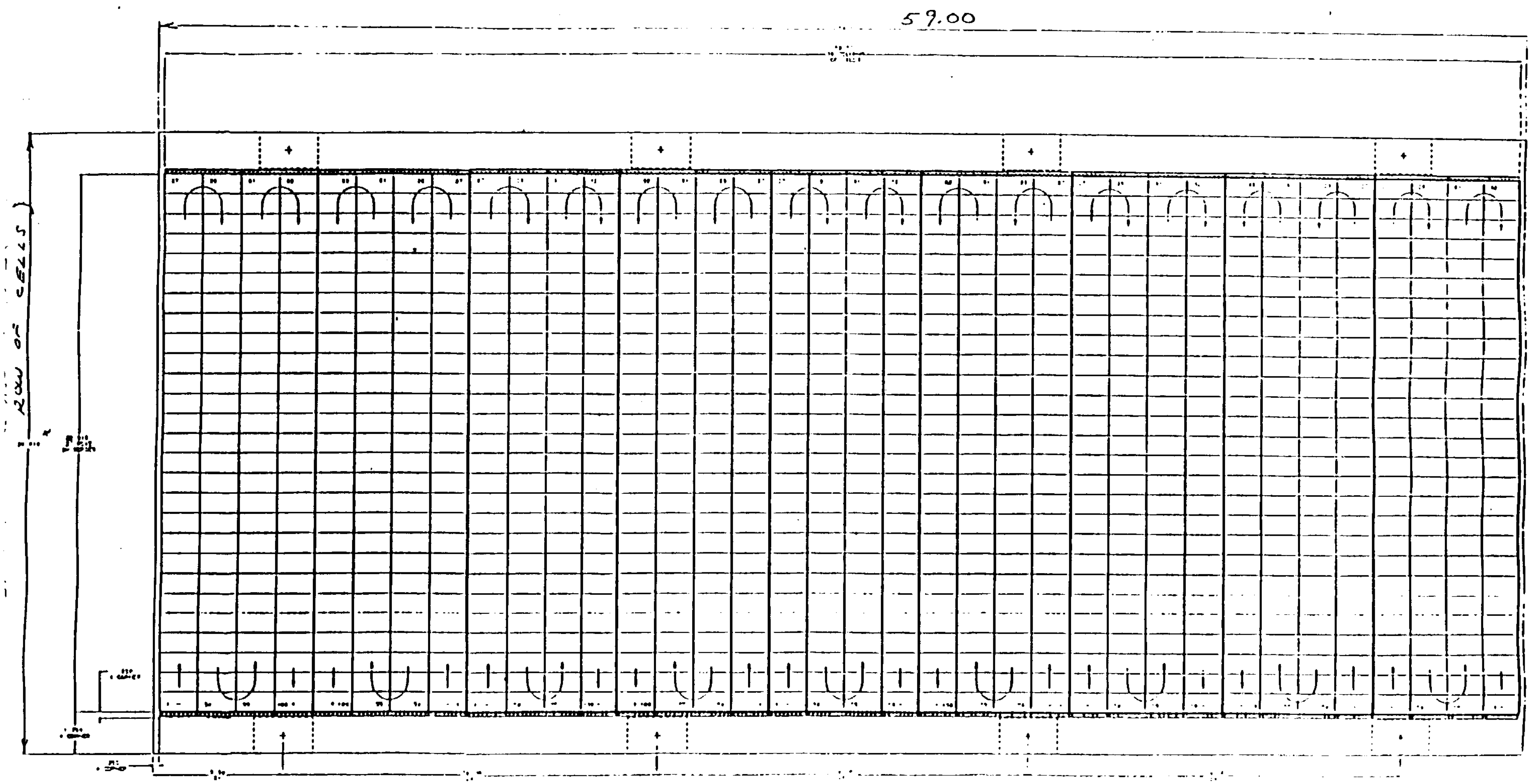
SSTI

Design Key Features - (Con'td.)

TRW

- Stowed Support Statically Determinate In-plane
  - Prevents solar array from reacting primary loads.
  - Absorbs relative thermal deflection.
  - Simplifies integration. Avoids in-plane "over-constraint" Interferences.

- External clevis fittings (similar to hinge clevis) transfer stowed pre-load through panels to support structure.
- Panel pre-load provided by separation nut at four locations on each wing.
  - Separation nut bolted to aluminum housing.
  - Bolt and spherical washers plus oversized hole used to attach separation nut housing to structure and accommodate angular tolerance between array and structure.
  - A specified rotation of bolt following bottoming out will be used to establish pre-load.
    - = Compliance of pre-load path TBD by analysis
    - = Strength of load path high relative to pre-load requirement. Therefore high precision not needed.
- Flexible leaf-spring guide to prevent impact load between panels and separation nut housing if contact occurs during deployment.

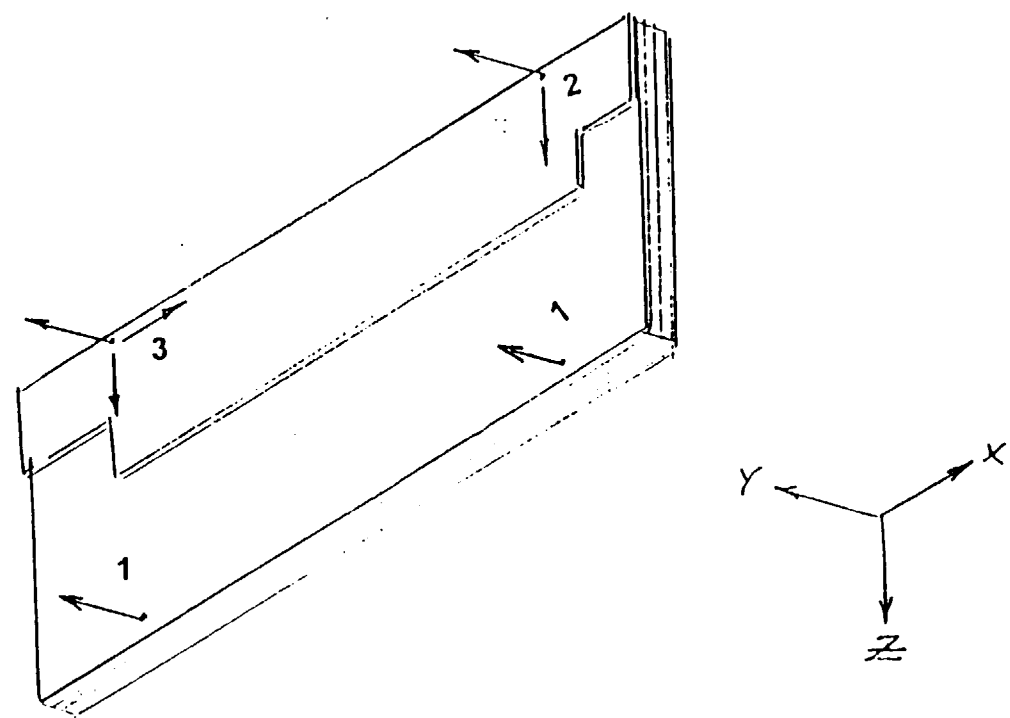


Cell Layout

3 ≡ BI- directional serrated plate

2 ≡ Uni-directional serrated plates plus flexures flexible in X-direction

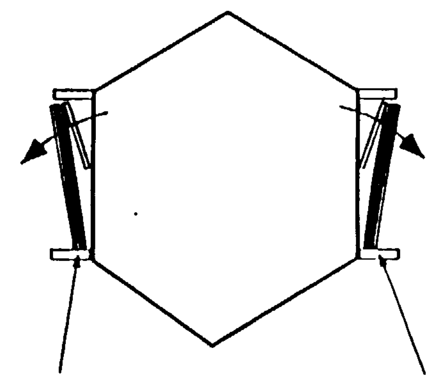
1 = Smooth surfaces plus flexures flexible in both X- and Z-directions



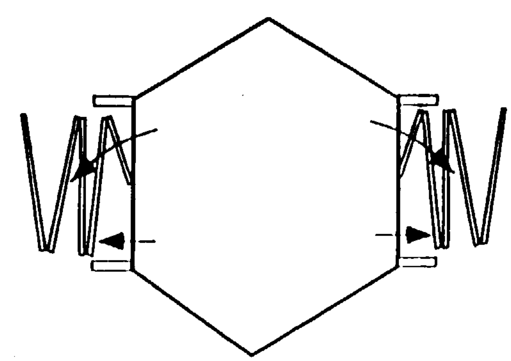
Stowed Reactions

PRELIMINARY 4 PANEL SOLAR ARRAY DEPLOYMENT RESULTS

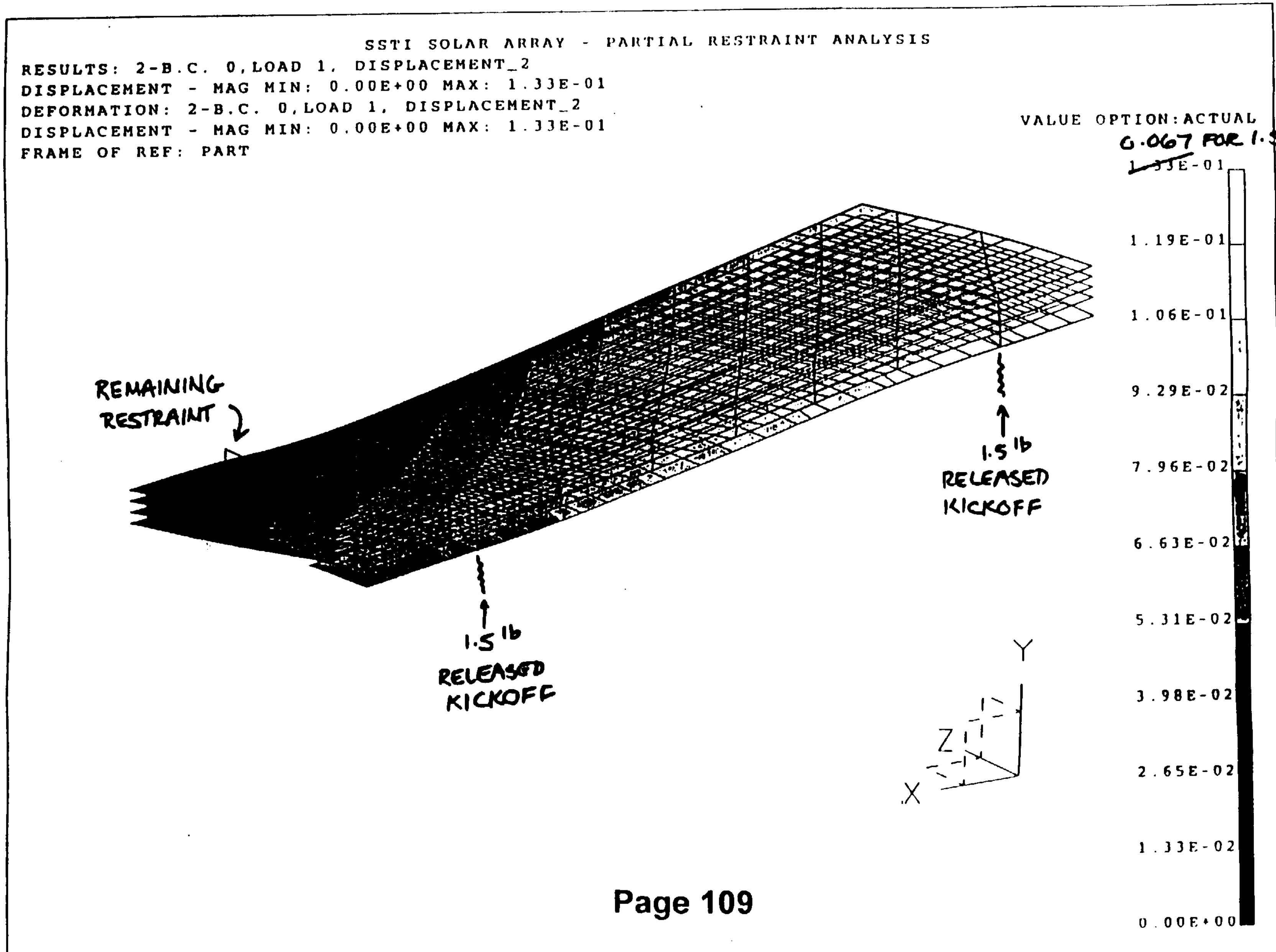
- USE ESTIMATED DEPLOYMENT AND LOCKUP TORQUES SUPPLIED BY STRUCTURES.
- ASSUMING NO RELEASE DEVICE HOUSING PROBLEM, DEPLOYMENT TO LOCKUP OF ALL STRAIN ENERGY HINGES SHOULD OCCUR WITHIN 20 SECONDS.
- WITHOUT KICKOFF SPRINGS, THE SOLAR ARRAYS WILL IMPACT AND POSSIBLY LOCKUP ON RELEASE DEVICE HOUSINGS.
- KICKOFF SPRINGS (0.5 TO 1.0 LB/IN FOR 1 INCH STROKE) WILL PREVENT IMPACT OF RELEASE DEVICE HOUSINGS.



YOKE DRIVES PANEL EDGES INTO RELEASE DEVICE HOUSINGS.



KICKOFF SPRING LOADS PREVENTS PANEL EDGES FROM IMPACTING RELEASE DEVICE HOUSING


SSTI SOLAR ARRAY - PARTIAL RESTRAINT ANALYSIS
RESULTS: 2-B.C. 0,LOAD 1, DISPLACEMENT_2
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 1.33E-01
DEFORMATION: 2-B.C. 0,LOAD 1, DISPLACEMENT_2
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 1.33E-01
FRAME OF REF: PART
VALUE OPTION:ACTUAL
0.067 FOR 1.5 lb
~~1.33E-01~~
1.19E-01
1.06E-01
9.29E-02
7.96E-02
6.63E-02
5.31E-02
3.98E-02
2.65E-02
1.33E-02
0.00E+00
REMAINING RESTRAINT
1.5 lb RELEASED KICKOFF
1.5 lb RELEASED KICKOFF
Y
Z
X

SSTI

Requirements/Capabilities/Verification Approach

Requirement	Source	Capability	Verification[1] Approach: A	I	F.C.	T
• Mounting provisions for payloads and bus equipment.	MDI EDI Thermal	Complies (or will when design complete)		X	X	
- Attachments			X	X	X	X
- Surface Area			X	X		
- Volume				X	X	
- Accessibility				X	X	
- F.O.V.			X	X		
- Thermal Paths			X			X
- Electrical Paths			X	X		X
• LV Shroud Envelope Compatibility	MDI Envelope	Complies	X	X		
• LV Mechanical I/F Geometric Compatibility		37.15 in. bolt circle per Lockheed drawing (LV & SC drilled to same template)		X	X	

(1) A = Analysis, I = Inspection, F.C. = Fit Check, T = Test

SSTI

Requirements/Capabilities/Verification Approach
(Cont'd.)

TRW

Requirement	Source	Capability	Verification[1] Approach: A	I	F.C.	T
• Minimum cantilevered frequency stowed	SY26-005 3.2.1.2.6					
15 Hz Lateral		18Hz Lateral	X			X
30 Hz Axial (LV Thrust Axis)		66 Hz Axial	X			X
• Launch Inertial Loads affecting primary load path,	LV Contractor	- Primary structure designed for Pegasus				
± .25G Lateral [2]		load factors which	X			X
+ 4.0, -8.0 Axial [2]		envelope LLV loads	X			X
Applied simultaneously		by a factor >2				

[2] Preliminary load factors to be used prior to first load cycle.

SSTI

Requirements/Capabilities/Verification Approach
(Cont'd.)

TRW

Requirement	Source	Capability	Verification[1] Approach: A	I	F.C.	T
• Launch Vibro-Acoustic Environment	EV1-034 EV2-099					
- Maintain Equipment Response due to vibro-acoustic environment within equipment acceptance limits.		Complies [3]	X[4]			X[5]
- Provide adequate strength at equipment mounts		- See weight vs. G curve (used for tested AB600)	X			X

[3] Based on scaling the AB600 acoustic test results.
[4] Combined LV+SC VAPEPS analysis is planned.
[5] Acoustic response test on structure with mass simulators.

SSTI

Requirements/Capabilities/Verification Approach

(Cont'd.)

Requirement	Source	Capability	A	I	F.C.	T
• Solar array structure adequate for Vibro-acoustic environment		- Design loads envelope predicted vibro-acoustic response 15 G Axial 10 G Out-of-Plane 6 G In-Plane, Lat. Simultaneous	X			X
• Solar array lowest mode separated from fundamental spacecraft lateral mode, to avoid dynamic coupling during launch		.35 Hz predicted (2 times fundamental spacecraft mode)	X			X
• Solar array deployed frequency > .3 Hz		.35 Hz predicted for 6 panel wing. Current design will have higher frequency	X			X(6)

Verification(1) Approach

(6)Stiffnesses of critical parts of deployed load path will be tested (e.g. Hinges).

SSTI

Requirements/Capabilities/Verification Approach

(Cont'd.)

Requirement	Source	Capability	Verification[1] Approach: A	I	F.C.	T
• On-orbit jitter limits HSI 10 μ RAD < 250 Hz 2 μ RAD > 1500 Hz	Payload Systems Engineer	Analysis shows limits met for HSI cryo-cooler disturbances (balanced)	X			X[7]
LEISA 30 μ RAD		TBD	X			X[7]

[7] Frequency predictions and damping values used in jitter analysis will be confirmed by test.

Requirements/Capabilities/Verification Approach

(Cont'd.)

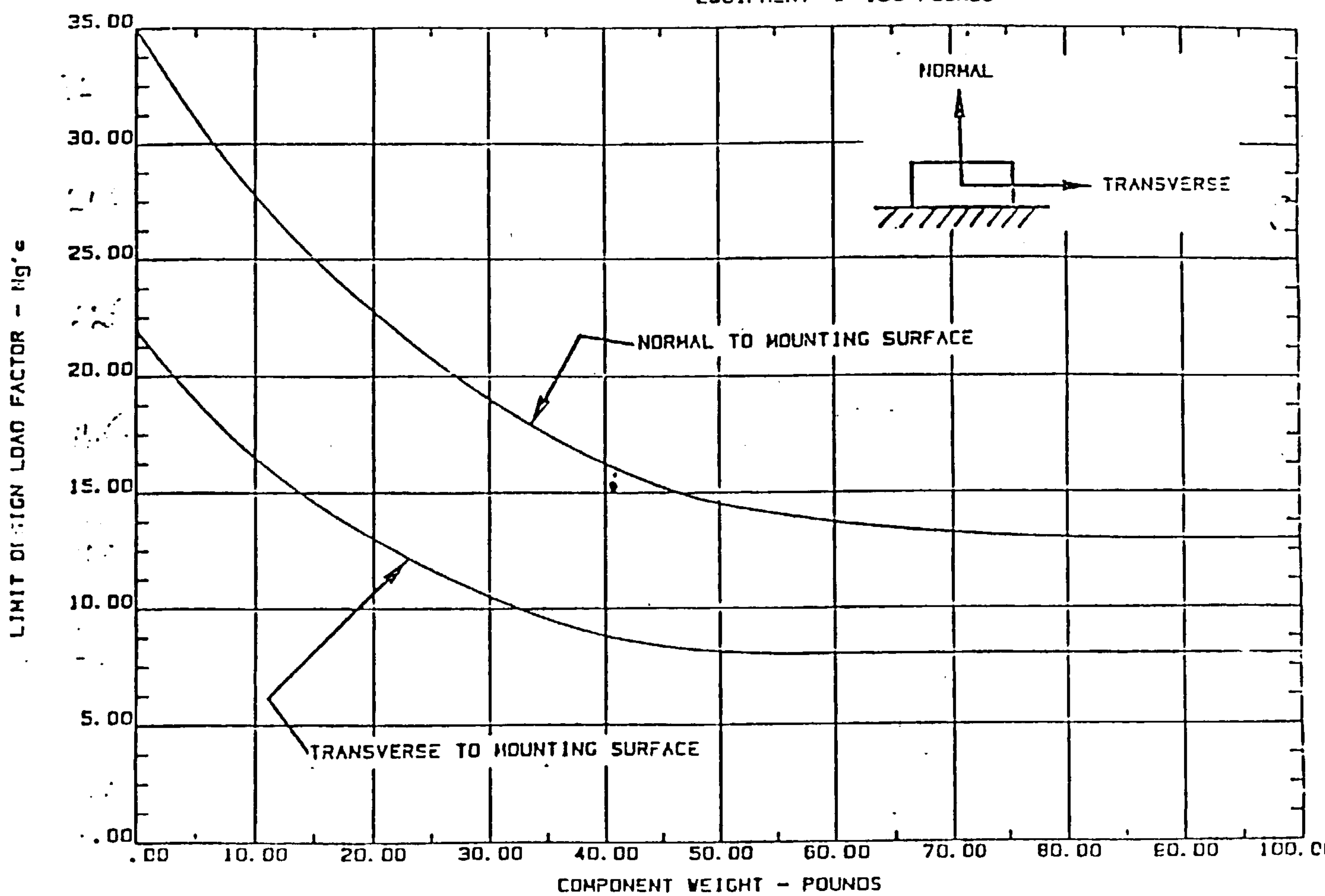
Requirement	Source	Capability	Verification[1] Approach: A	I	F.C.	T
• Incorporate thermal control features needed	Thermal Engineer					
- Panel & Joint Thermal Conductivities		Thermal Control requirements are incorporated in design	X			X[8]
- Equipment-Panel			X			X
- Equipment Panel - Radiator Joint Conductors			X			X
- Thermal Coatings			X	X		
- Inserts on Battery Panel for Heat Pipe			X	X		
- Provisions for MLI attach.			X	X		
• Contamination Control		Sealed Insulation plus vent paths direct contamination products away from critical surfaces	X	X		

[8] Laminate thermal conductivity testing; box panel conductance tests.

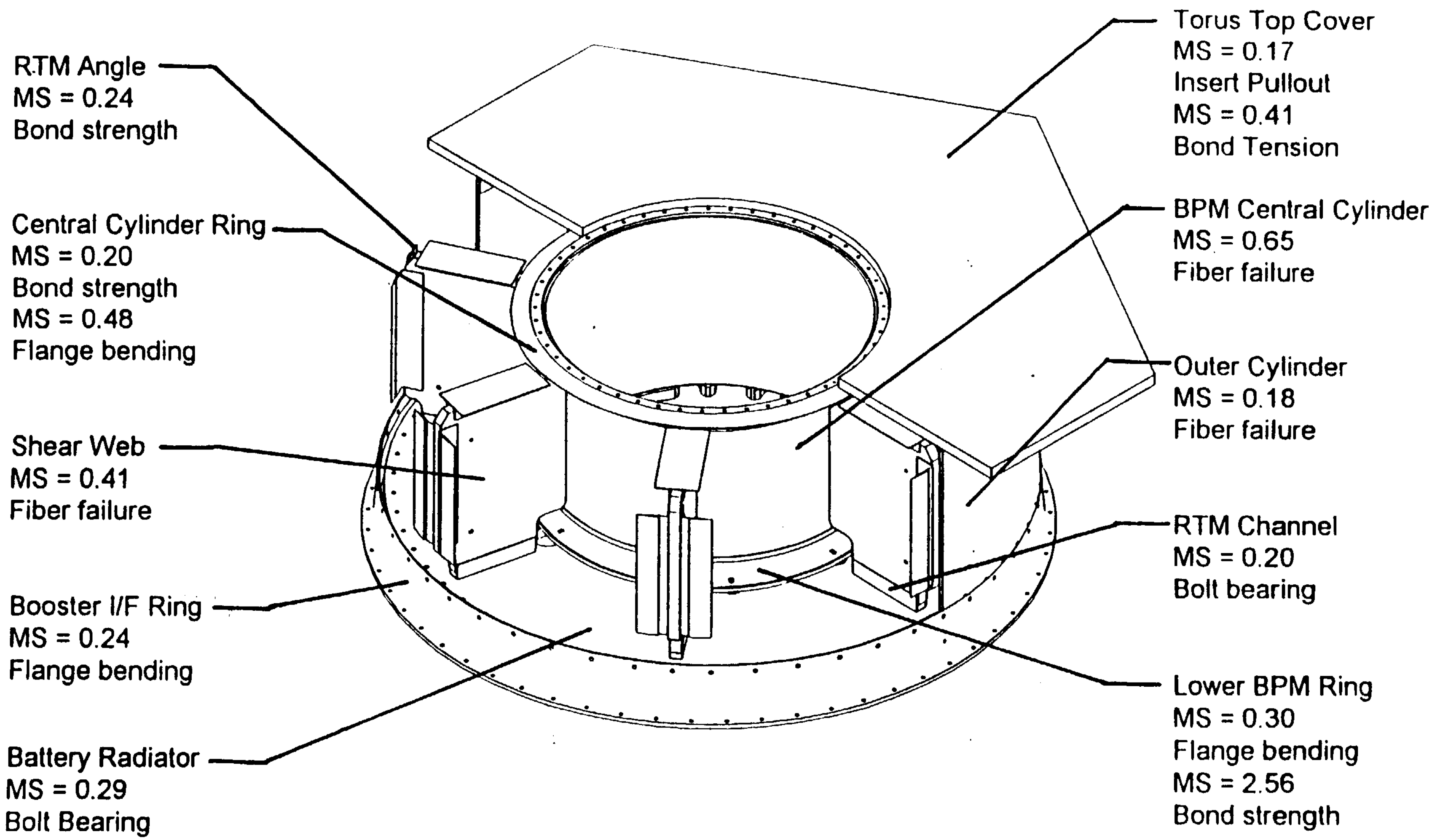
SSTI

EQUIPMENT INSTALLATION LIMIT DESIGN LOAD FACTORS

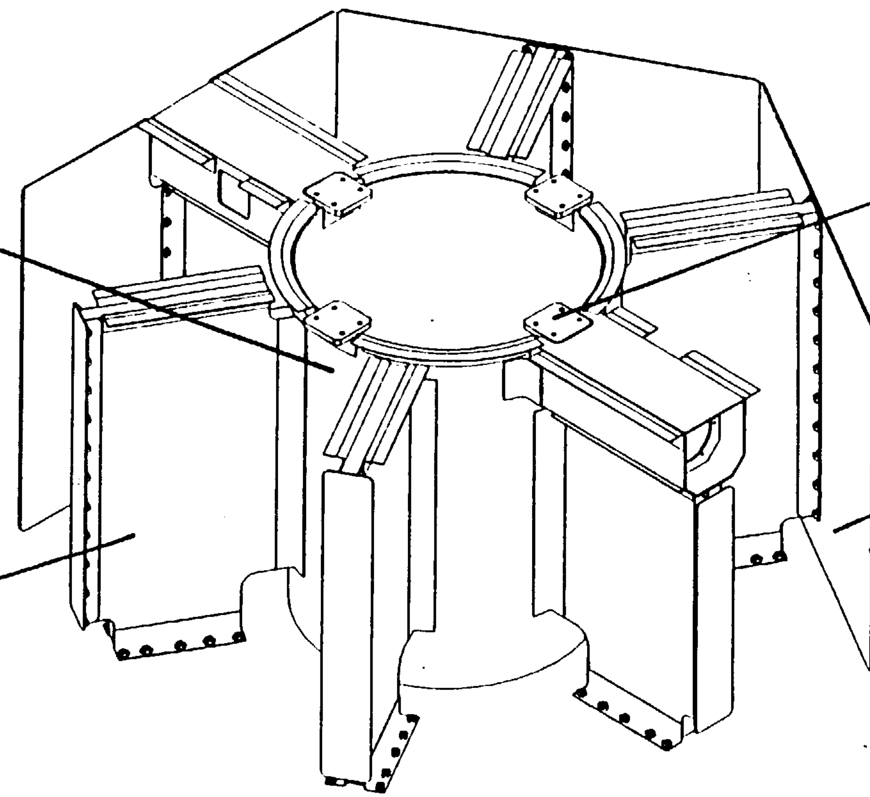
EQUIPMENT ≤ 100 POUNDS



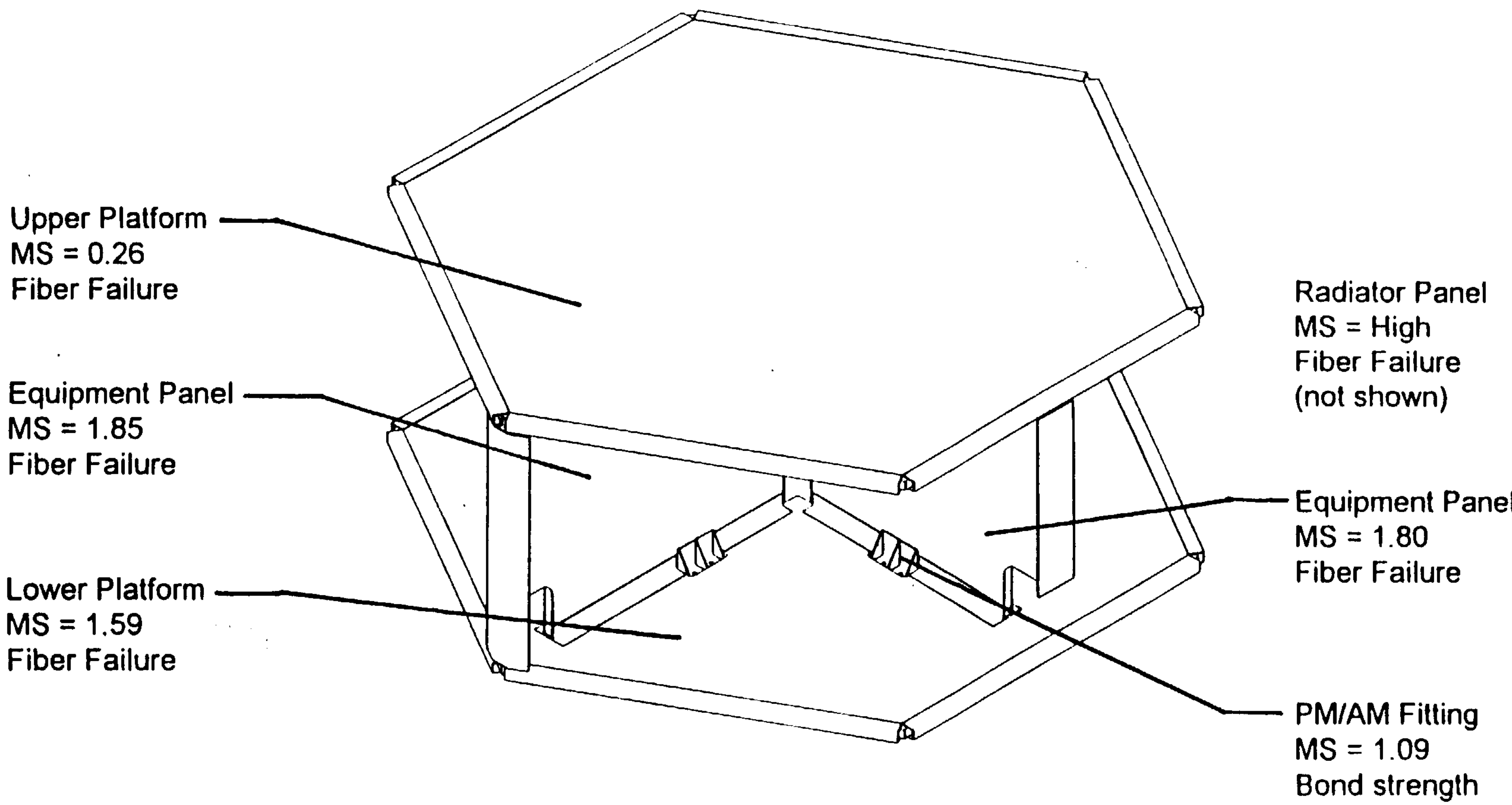
Margin of Safety Summary



Margin of Safety Summary



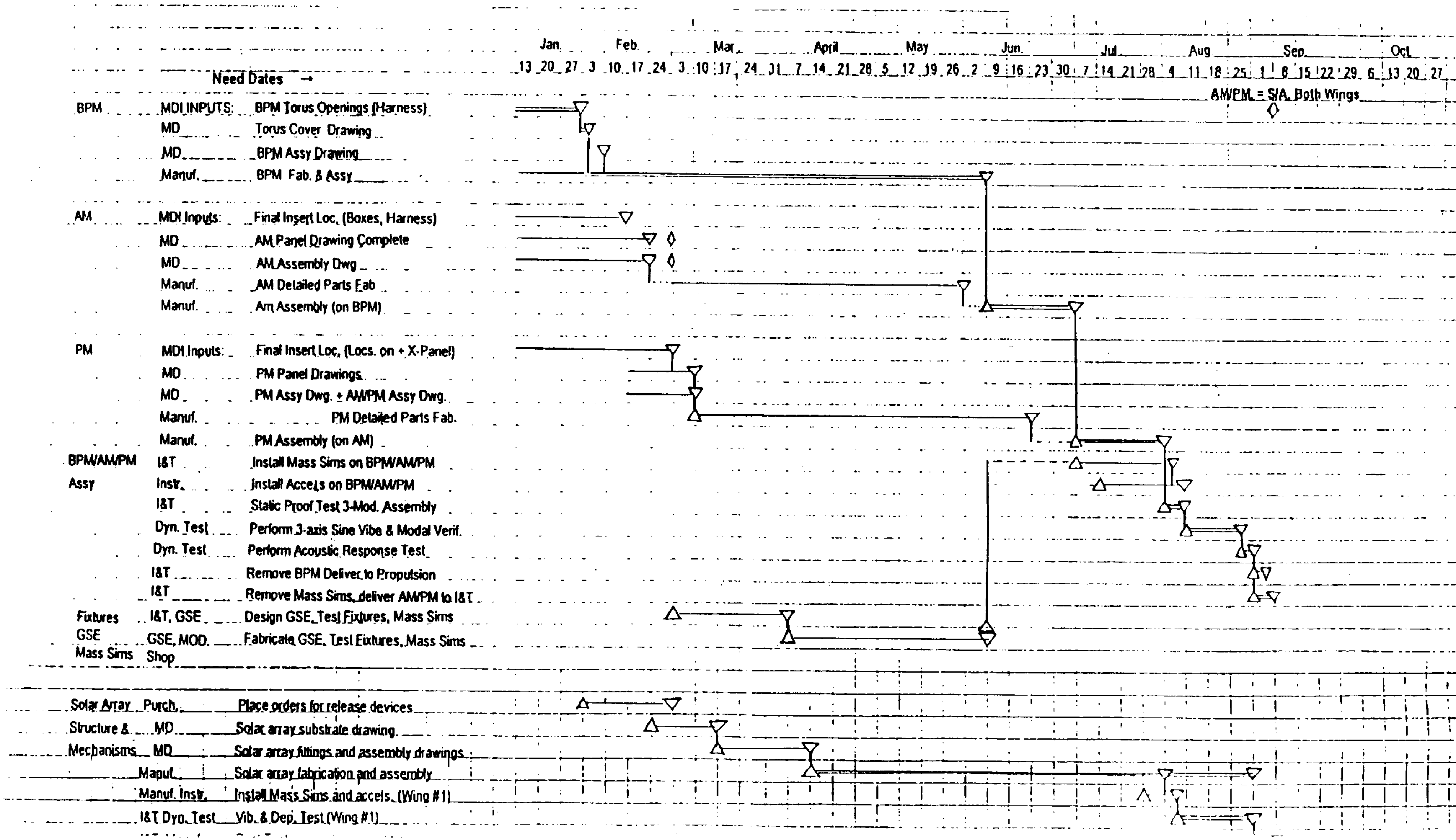
Margin of Safety Summary



Planned Tests

- **Development Tests**
  - Solar array hinge stiffness, $T \sim \Theta$
  - Solar array harness $T \sim \Theta$ hot, cold ambient
  - AM/PM joint fittings : bond joint strength test
  - thermal interface conductance with dimpled foil: capability to maintain conductance thru vibe, thermal cycles; box-panel, radiator-panel.
- **Bus and Payload Module Tests**
  - Static strength-stiffness test of primary load path of BPM/AM/PM assembly.
  - 3-axis vibration test of BPM/AM/PM assembly with mass simulators: strength verification; modal verification. Acoustic test to verify that equipment response is within acceptance limits.
- **Solar Array Tests**
  - Vibration test of stowed wing with mass simulators: design qualification.
  - Full deployment test of wing with mass sims.

SSTI Structure Subsystem Integrated Summary Schedule



31

SSTI THERMAL CONTROL

Critical Design Audit
January 19, 1995

David Antoniuk
Rick Hardgrove
Richard Wylie

SPACECRAFT OVERVIEW

- Three Modules comprise Spacecraft Bus

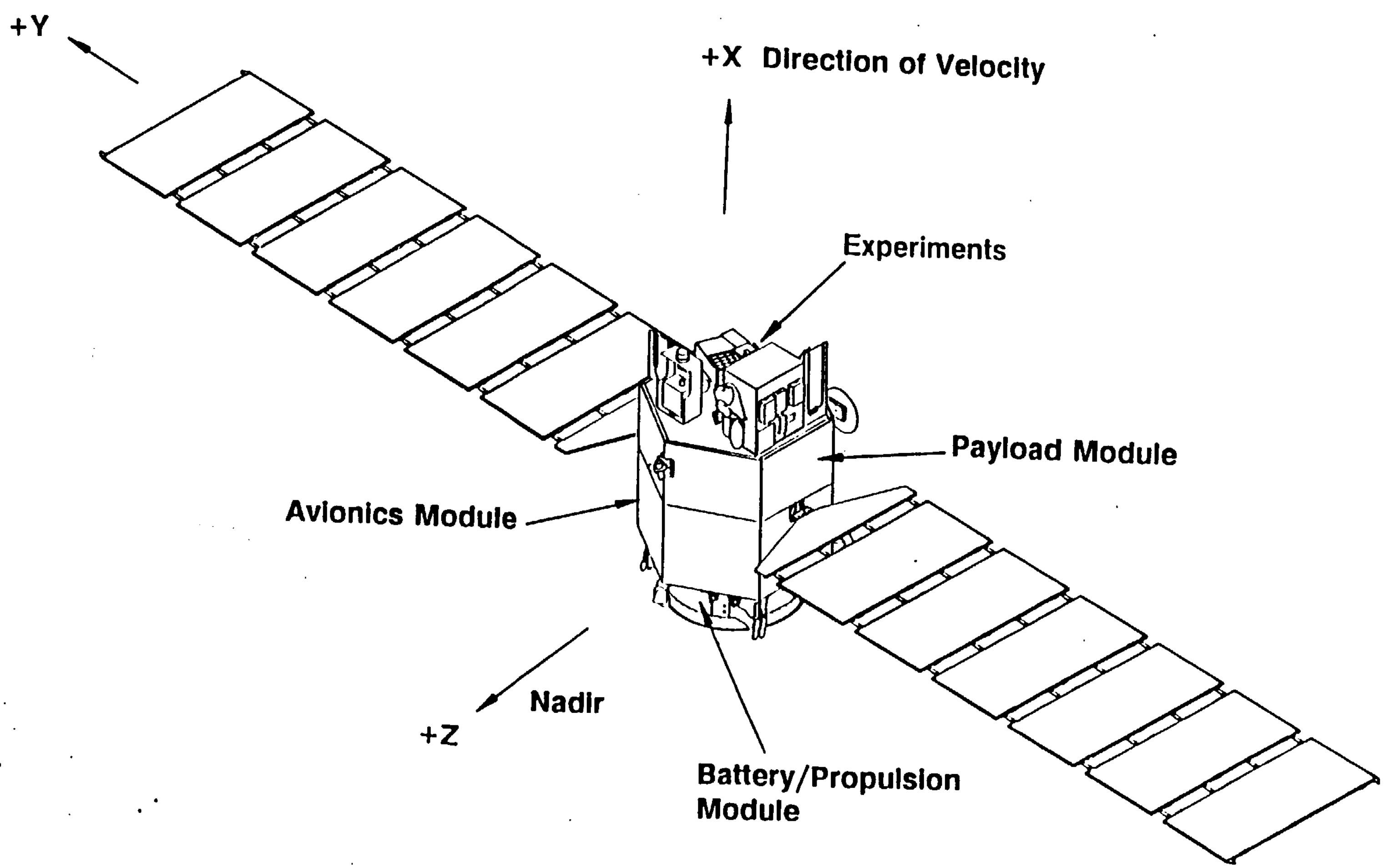
  BPM - Battery-Propulsion Module

  AM - Avionics Module

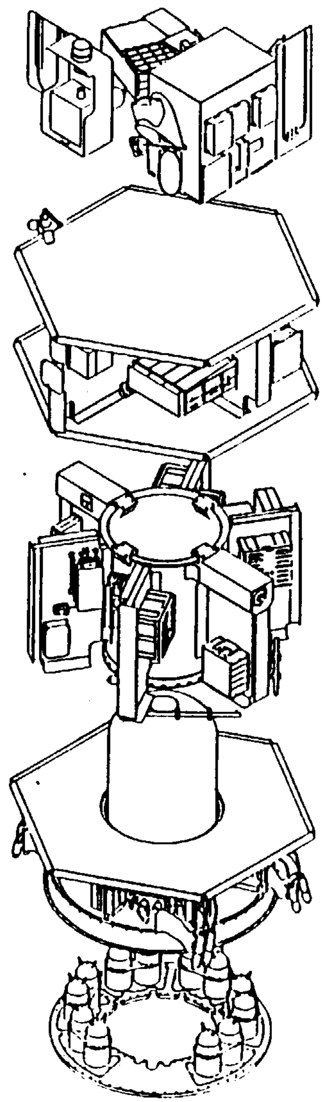
  PM - Payload Module

- Payload Instrument Platform
- Solar Array Assembly

Spacecraft


+Y
+X Direction of Velocity
Experiments
Payload Module
Avionics Module
Nadir
+Z
Battery/Propulsion
Module

Spacecraft Modules



Experiments
(Not covered in ICDA)

Payload

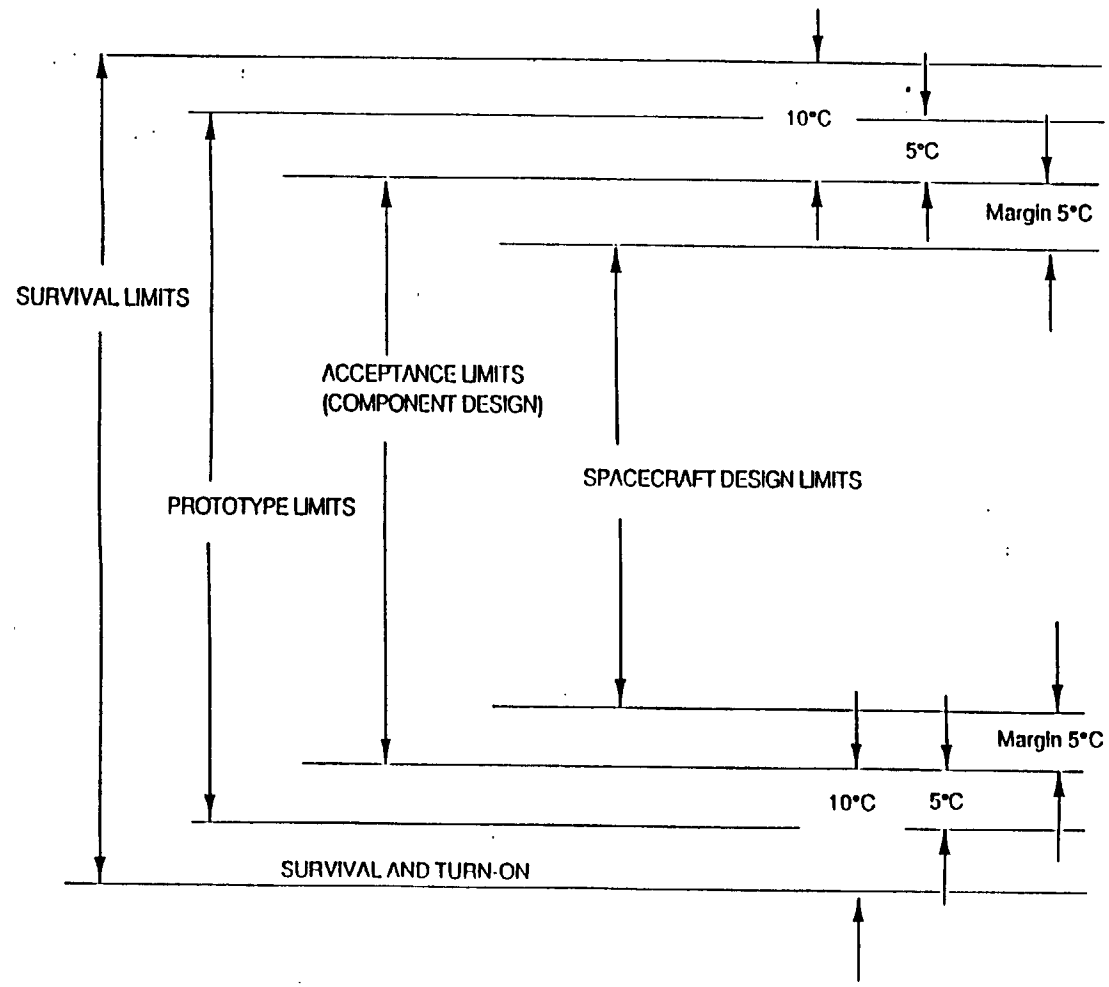
Avionics

Battery and Propulsion

Requirements vs. Capabilities

Source	Requirement	Capability	How Verified
EV2-099	Thermal Control Subsystem will maintain components within their required operating and non-operating temperature limits	Comply	Analysis, Thermal Vacuum Test
EV1-034	Altitude: 523 ± 10 km (282 ± 5 nm) Inclination: 97.45 degrees Ascension: 10:40 am ± 1.6 minutes Mission Life Goal: 5 years	Comply	Analysis, Thermal Vacuum Test
D22889	Thermal Control Subsystem will meet temperature requirements with specified unit power dissipations	Comply	Analysis, Thermal Vacuum Test
SR4-047	Thermal Control Subsystem weight will not exceed 5.0 kg	Comply	Analysis

Temperature Limit Requirements



POWER DISSIPATION AND TEMPERATURE CONTROL REQUIREMENTS

POWER IN WATTS

Subsystem	Unit	No. (No. On)	Duty Cycle	Orbit Avg	Sunlight Avg	Eclipse Avg	Acceptance Temp (°C) Min	Max
Guidance	GRA	3 (2)	100%	20.8	20.0	20.0	5	55
	TAM	1	100%	1.8	1.8	1.8	-20	55
	Coarse Sun Sensor	4	100%	0	0	0	-115	95
	Earth Sensor	3	100%	.1	.1	.1	-5	55
	RWA	4 (3)	100%	5.7	5.7	5.7	-5	50
	CEA	1	100%	10.7	10.7	10.7	-20	55
	Torque Rods	3	100%	1.4	1.4	1.4	-20	55
	VDE	2	0%	0.	0.	0.	-20	55
	SADA	2	8%	3.4	3.4	3.4	-24	61
	SADE	1	100%	1.5	1.5	1.5	-24	61
	NFOV Star Tracker	1	100%	11.0	11.0	11.0	-5	45
Data Management	S/C Computer	2 (1)	100%	23.5	23.5	23.5	-24	61
	DIU	2 (1)	100%	9.5	9.5	9.5	-24	61
	Transponder							
	Transmitter	2 (1)	10%	2.1	2.1	2.1	-20	55
	Receivers	2	100%	6.4	6.4	6.4	-20	55
Electrical Power	PCU	1	100%	12.9	12.9	12.9	-10	28
	DDC	1	0%	0.0	0.0	0.0	-20	35
	SAR	2	100%	27.6	27.6	8.6	-20	45
	Battery (Recharge)	1		165.0	276.0	0.0	0	25
	DC Harness	1		9.9	11.9	6.4	TBD	TBD
	Solar Array	2		0	0	0	-90	82
Tech Demo	GEM	1					-24	61
	SLAM	1	0%	0.	0.	0.		
	GPS	1	100%	6.0	6.0	6.0		
	Solar Cell	1	25%	.6	1.0	0.0		
	Heat Straps	1	100% (Sun)	.6	1.0	0.0		
	Solar Cells	1	100% (Sun)	0.0	0.0	0.0	90	82
	Reaction Wheel	1	100%	5.0	5.0	5.0	0	60
	GPC (Rad. Monitor)	1	100%	5.0	5.0	5.0	-10	55
	WFOV Star Tracker	1	0%	1.2.	1.2.	1.2.	-5	45

POWER DISSIPATION AND TEMPERATURE CONTROL REQUIREMENTS - Continued

POWER IN WATTS

Subsystem	Unit	No. (No. On)	Duty Cycle	Orbit Avg	Sunlight Avg	Eclipse Avg	Acceptance Temp (°C) Min	Acceptance Temp (°C) Max
Payload Support	SS Recorder	1	VAR	16.4	16.4	16.4	-24	61
	PEA	1	100%	24.1	24.1	24.1	-24	61
Payload Instrument	HSI	1	100%	43.8	45.5	41.3	-13	27
	LEISA	1	100%					
	FPA			<.4 (A)	<.4 (A)	<.4 (A)	78°K	83°K
	Cryocooler							
	Cold Head			0.	0.	0.	73°K	78°K
	Heat Sink			18.0	18.0	18.0	-10	25
	Bench			8.0	8.0	8.0	0	30
	OPA	1		5.4	5.4	5.9	-24	61
	UCB	1		12.4	10.3	15.3	-15	45
Propulsion	DTMs (B)		0%	0	0	0	4	955
	Iso Valves		0%	0	0	0	4	94
	Press. Transducer		100%	.5	.5	.5	4	72
	Prop. Tank		0%	0	0	0	4	32
	Filters		0%	0	0	0	4	72
	F&D Valve		0%	0	0	0	4	72
	Latch Valve		0%	0	0	0	4	72

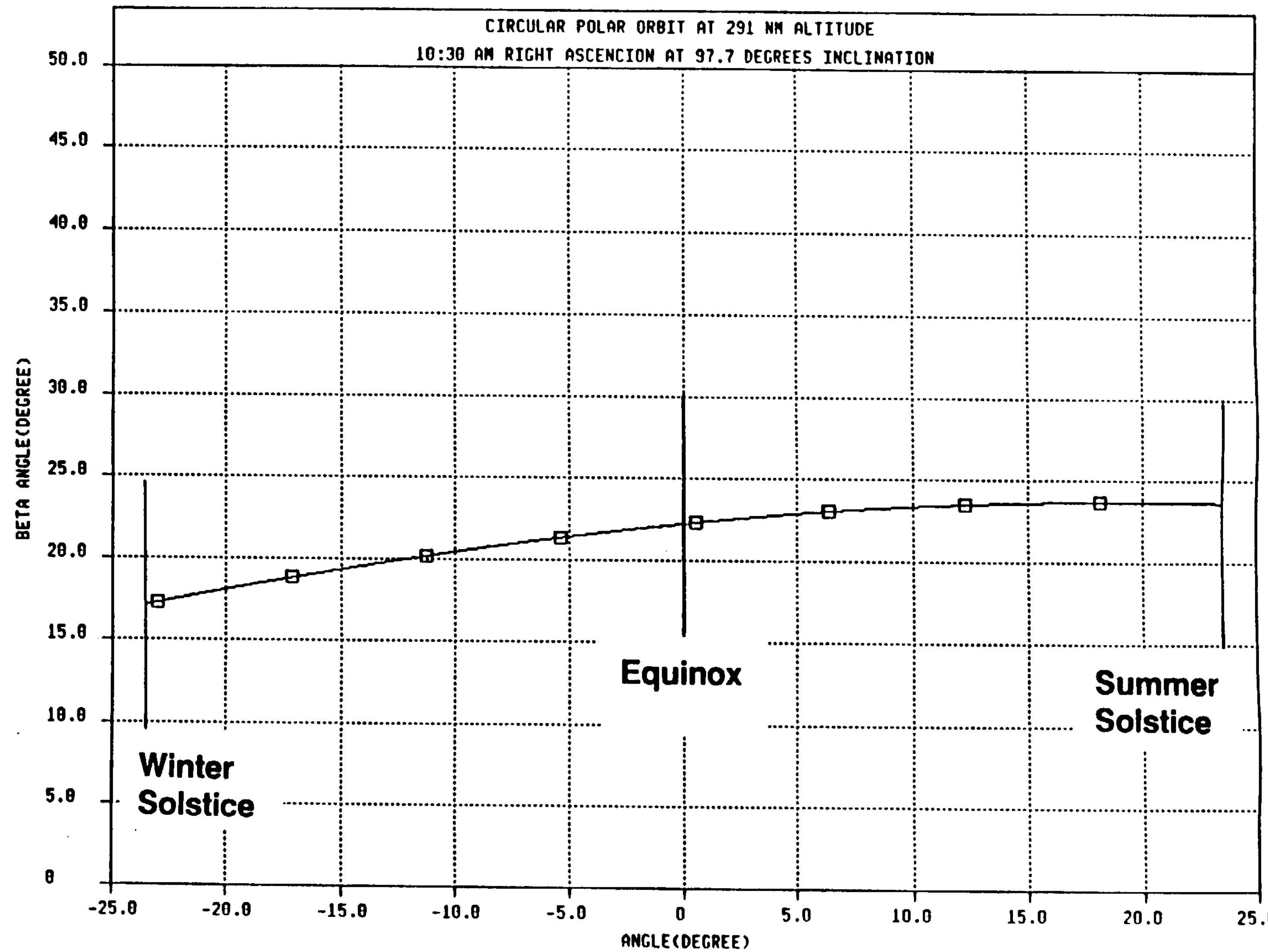
(A) FPA Dissipation & Parasitic Loads

(B) Nozzle exit view only; otherwise, limit is 93°C

Environmental Heating Parameters		
Solar Radiation (1 σ deviation)	Minimum	Maximum
Winter:	434 Btu/ft^2-hr	450 Btu/ft^2-hr (A)
Equinox:	421 Btu/ft^2-hr	442 Btu/ft^2-hr
Summer:	408 Btu/ft^2-hr (B)	421 Btu/ft^2-hr
Albedo	0.3 (B)	0.35 (A)
Earth Radiation	72 Btu/ft^2-hr (B)	79 Btu/ft^2-hr (A)
Apparent Sun Angle (degrees)	Winter:	17.1 (A)
	Equinox:	22.3
	Summer:	23.7 (B)
Maximum Eclipse	35.3 minutes	

(A) Hot Case Design Criteria
(B) Cold Case Design Criteria

Seasonal Variation of Angle Between Solar Vector and Orbit Plane



Optical Properties

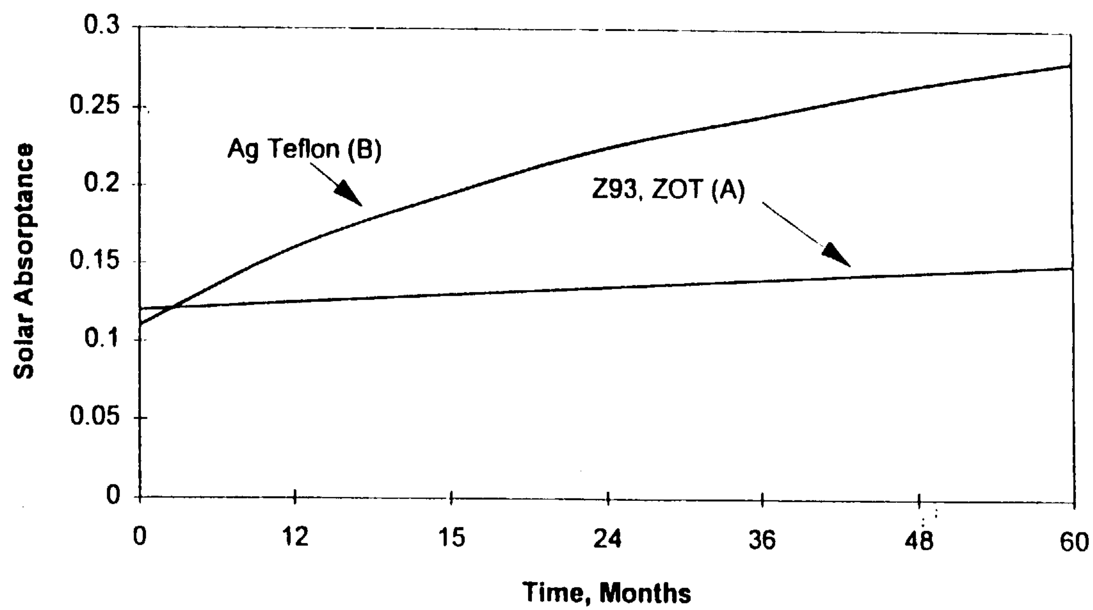
Surface	Thickness (Mils)	Solar Absorptance, α		Hemispherical Emittance, ϵ (A)
		BOL (A)	EOL	
Silverized Teflon	5.0	0.08	0.30 (A,B)	0.78
Z-93 White Paint	> 6.0	0.17	0.20 (B,C)	0.87
ZOT White Paint	> 6.0	0.14	0.20 (B,C)	0.86
Aluminized Kapton (Kapton side)	2.0	N/A	N/A	0.78
Aluminized Kapton (Kapton side)	1.0	N/A	N/A	0.66
Aluminized Kapton (Kapton side)	0.5	N/A	N/A	0.56
Aluminized Kapton (Aluminum side)	N/A	N/A	N/A	0.03 ± .01
Aluminized Teflon	5.0	0.13	0.35 (D)	0.78
GFRP (Typical)	N/A	0.92 (E)	N/A	0.82 (E)
Solar Cell	8.0	0.72 (F)	0.79 (F)	0.81

For all α and ϵ values, a ± 0.02 tolerance applies except where specified otherwise
End-of-life values reflect a five-year orbital lifetime

Notes:

(A) Thermophysics Data Base
(B) 0.02 has been added to worst case data to agree with projected LDEF results
(C) LDEF Final Report
(D) Derived from Silverized Teflon $\Delta\alpha$
(E) Based on 1993 measurements by TRW Thermophysics Lab
(F) Includes solar cell electrical efficiency

Property Degradation for Radiator Material



(A) LDEF Final Report

(B) TRW Thermophysics Data Base (Assumes Contamination)

SSTI

Design Properties/Criteria - Continued

Interface Conductances		Comments
Component baseplate to aluminum-covered GFRP	10 Btu/Hr-Ft^2-°F	For low-dissipation components
GFRP to GFRP	10 Btu/Hr-Ft^2-°F	For non-critical interfaces
GFRP to GFRP, each aluminum covered, with aluminum foil interface filler	50 Btu/Hr-Ft^2-°F	Needs development test to verify
Interface filler (RTV) to both GFRP and Al	50 Btu/Hr-Ft^2-°F	Used to mount electronic components
Effective Multi-layer Insulation Emittance ϵ*	0.02	Nominal value used for preliminary analysis

All values are based on measurements from TRW Thermophysics Laboratory, and will be verified in the systems-level T/V Thermal Balance Test

Material	Lateral Conductivity	Through Conductivity	Density	Specific Heat
	Btu/hr-ft-°F	Btu/hr-ft-°F	lbm/ft^3	Btu/lbm-°F
M60J GFRP	27 (A)	0.56 (A)	104	0.22
P100 GFRP	90	0.56	112	0.22
K1100 GFRP	310 (A)	0.56 (A)	116	0.35
T300 GFRP	1.6	0.56	98.5	0.22
Aluminum	90	90	170	0.22

(A) "Thermal Conductivity of K1100 Graphite Composites," by W. R. Hardgrove and L. R. Kelley, unpublished (Note: Included measurements for M60J GFRP)

Spacecraft Thermal Properties

Battery-Propulsion Module

Panel	H/C Core Thickness	H/C Density	Conductance Through Honeycomb	Facesheet Material Layup (A)	F/S Layup Thickness	Total F/S Thickness	Thermal Conductivity Btu/hr-ft-°F	
	inch	lbm/ft³	Btu/hr-ft²-°F		inch	inch	Ko(B)	Kx
Adaptor Ring	N/A	N/A	N/A	7075 AL	N/A	0.100	90	90
Torus	0.188	4.5	80	M60J	N/A	0.012	27	27
Central Cylinder, Lower	0.125	3.1	80	T300	N/A	0.019	1.6	1.6
Torus Bottom Cover	0.50	6.1	40	M60J	N/A	0.060	27	27
Shear Webs	0.61	3.1	16	T300	N/A	0.020	1.6	1.6

Notes:

(A) Inner and outer facesheets assumed symmetrical; K1100 is unidirectional in lateral, circumferential, and radial directions; GFRP other than K1100 is isotropic

(B) In K1100 direction

Spacecraft Thermal Properties

Avionics Module

Panel	H/C Core Thickness	H/C Density	Conductance Through Honeycomb	Facesheet Material Layup (A)	F/S Layup Thickness	Total F/S Thickness	Thermal Conductivity Btu/hr-ft-°F	
	inch	lbm/ft³	Btu/hr-ft²-°F		inch	inch	Ko(B)	Kx
Top Torus Cover	0.61	3.1	16	M60J	N/A	0.018	27	27
Equipment Panel	1.0	4.5	15	M60J/K1100	0.019/.006	0.025	95(C)	27
Central Cylinder	0.125	3.1	80	M60J/K1100	0.019/.006	0.025	95(C)	27
Outer Panel	0.125	3.1	80	P100/K1100	0.012/.003	0.015	98(C)	45

Notes:

(A) Inner and outer facesheets assumed symmetrical; K1100 is unidirectional in lateral, circumferential, and radial directions; GFRP other than K1100 is isotropic

(B) In K1100 direction

(C) Nominal value of 90 Btu/hr-ft-°F used for design

Spacecraft Thermal Properties

Payload Module

Panel	H/C Core Thickness	H/C Density	Conductance Through Honeycomb	Facesheet Material Layup (A)	F/S Layup Thickness	Total F/S Thickness	Thermal Conductivity Btu/hr-ft-°F	
	inch	lbm/ft³	Btu/hr-ft²-°F		inch	inch	Ko(B)	Kx
Lower Platform	0.61	3.1	16	M60J	N/A	0.018	27	27
Equipment Panel	0.61	3.1	16	M60J/K1100	0.018/.006	0.024	98(C)	27
Outer Panels (4)	0.25	4.5	60	M60J/K1100	0.024/.009	0.033	104(C)	27
Outer Panels ±Y only	0.50	6.1	40	M60J/K1100	0.024/.009	0.033	104(C)	27
Upper Platform	0.61	3.1	16	M60J	N/A	0.018	27	27

Notes:

(A) Inner and outer facesheets assumed symmetrical; K1100 is unidirectional in lateral, circumferential, and radial directions; GFRP other than K1100 is isotropic

(B) In K1100 direction

(C) Nominal value of 90 Btu/hr-ft-°F used for design

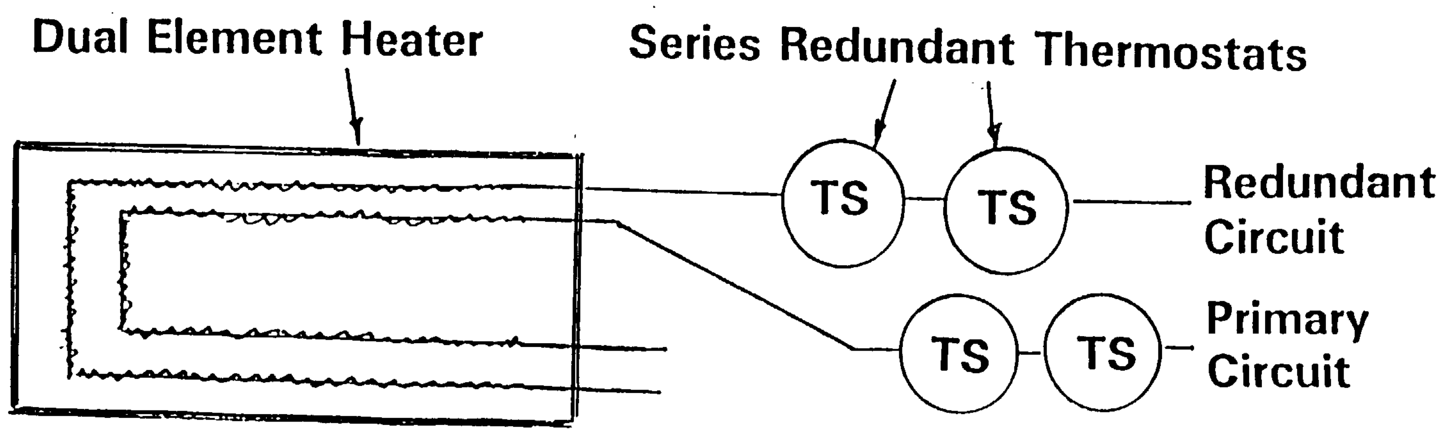
SSTI

Multi-Layer Insulation (MLI) - Summary

- Standard MLI blanket has 12 total layers with 10 internal filler layers
- Exposed MLI in ram direction (+x surface) has aluminized or silverized Teflon (5 mil) outer layer
- Exposed MLI on AM and PM radiator surfaces (non-ram direction) has aluminized Kapton (3 mil) outer layer
- Filler layers are aluminized Mylar
- Kapton side of inner blanket layer always faces spacecraft structure

Spacecraft Heater Characteristics

- Kapton film strip dual-element heaters selected from TRW heater specification 1S005, Heater, Electrical, Flexible (Kapton Insulation).
- Heaters will be controlled by mechanical thermostats selected from TRW specification 2F017, Switch, Thermostats, (Bimetallic), SPST.
- Typical installation will have redundant heater elements with series redundant thermostats.
- Heaters sized at worst-case minimum voltage of 24.0 V DC at 15% above nominal required power.
- Heater power strip density not to exceed 5 watts/in^2 at maximum voltage of 38.6 V DC.



SSTI

Thermal Interfaces

- Spacecraft to Payload Instrument Platform
  - All instruments isolated from S/C Bus
- Spacecraft to Launch Vehicle (LLV)
  - Requirements to be defined

SSTI

Spacecraft Modes of Operation

TRW

- Launch/Ascent - To Be Analyzed
- On-Orbit
  Normal Operation:

  End-of-Life (at 5 years) case is used for sizing radiators

  All units operating

  Maximum solar absorptance for external surfaces

  Maximum environmental heating

  Beginning-of-Life case is used for sizing heaters

  Low power during safe-hold mode and/or minimun power during normal operation

  Minimum solar absorptance for external surfaces

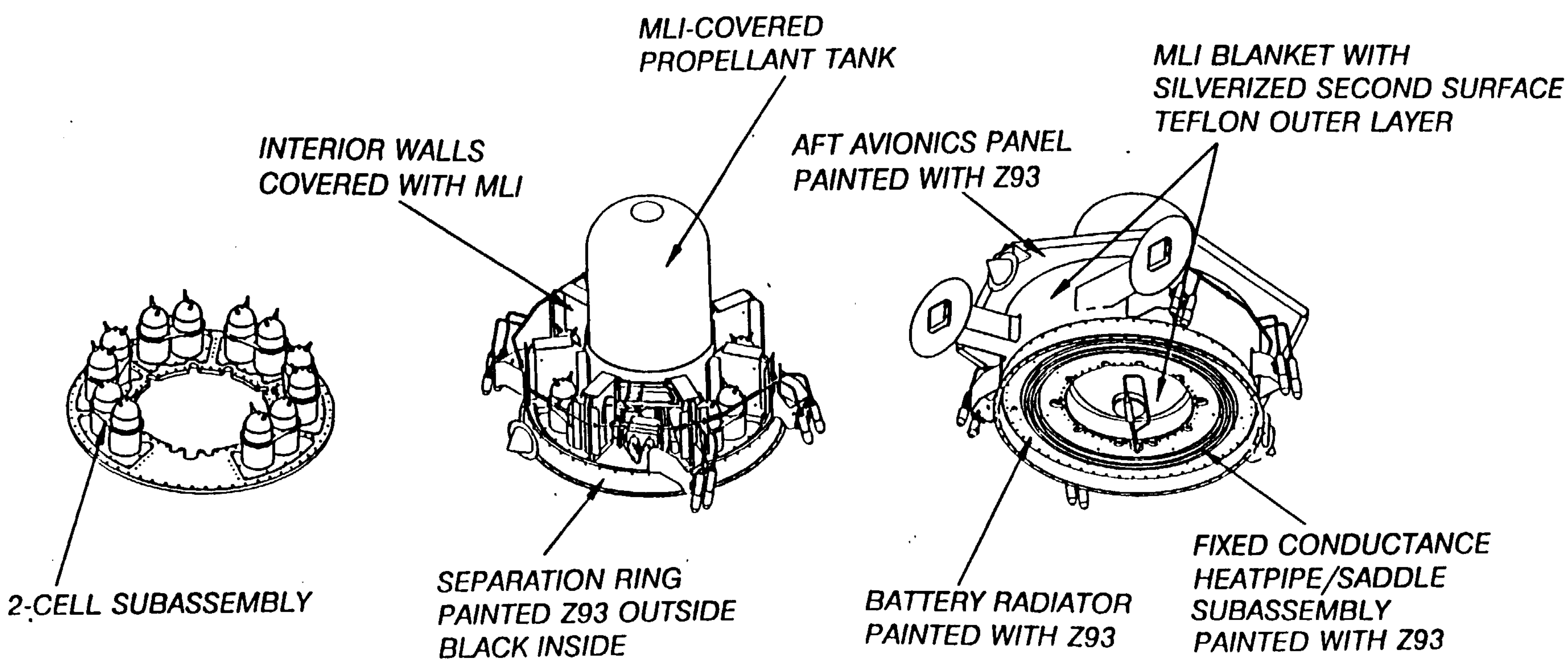
  Minimum environmental heating

THERMAL CONTROL SUBSYSTEM DESCRIPTION OVERVIEW

- All three modules reject heat through white-painted radiator surfaces
- Minimum required component temperatures maintained by use of thermostatically controlled heaters
- Panel area not needed for radiator area will be covered with multi-layer insulation that has an outer layer of second-surface silvered or aluminized Teflon
- GFRP structure has P100 or K1100 plies added where necessary to increase thermal conductivity
- The thermal design of each module will be optimized so that minimal heat exchange will occur among the modules

SSTI

Battery/Propulsion Module Design Approach



Battery Module Design Features

- o Battery aluminum baseplate spreads heat over 80% of compartment floor area
  - reduces requirement on support platform thermal conductance

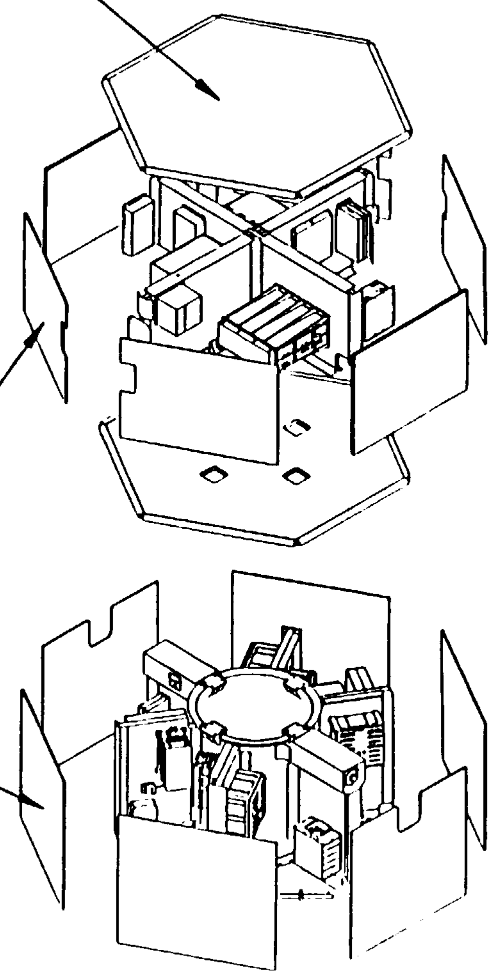
- o Battery radiator panel isolated from Avionics Module
  - inner cylinder and shear webs made from low-conductance T-300 GFRP
  - dry interface and T-300 bracket at coupling with outer cylinder
  - T-300 bracket between outer cylinder and AM floor
  - inner walls of each compartment covered with MLI blankets
  - batteries not covered with MLI to facilitate integration

- o Heatpipe assembly used to meet stringent battery thermal gradient requirement
  - required due to gradient-inducing effects of separation ring and appendages
  - two axial groove/ammonia FCHP's soldered to annular disc aluminum saddle
  - heatpipe assembly bolted to radiator-side of battery platform
  - contamination source-free dimpled aluminum foil between saddle and radiator
  - radiator panel and heatpipe assembly coated with Z93 paint

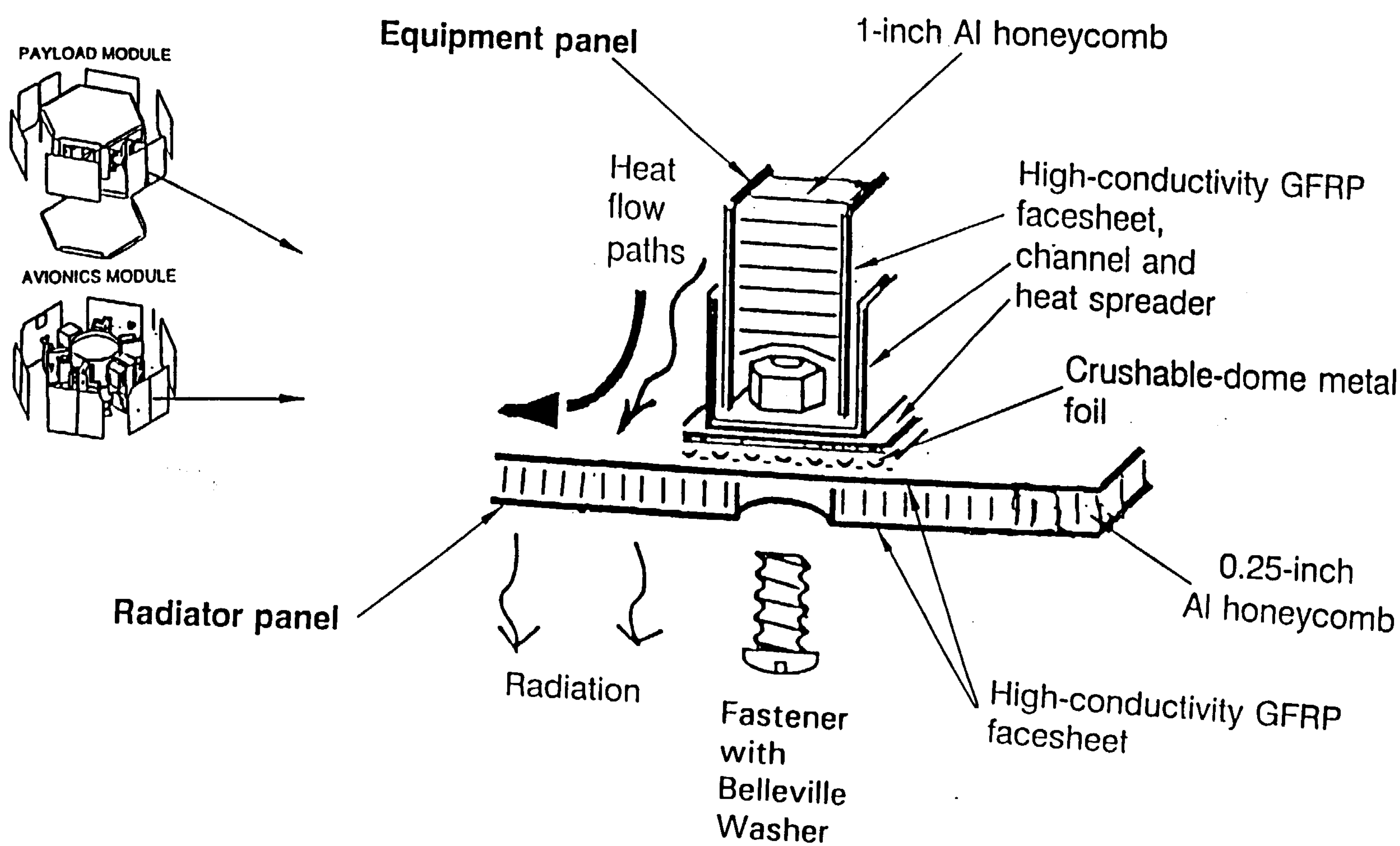
- o Dual optical properties for separation ring
  - ring not covered with MLI
  - Z93 paint on outer surfaces
  - high emittance/absorptance black paint on inner surfaces to reduce reflected solar flux on battery radiator panel

Avionics and Payload Modules Design Approach

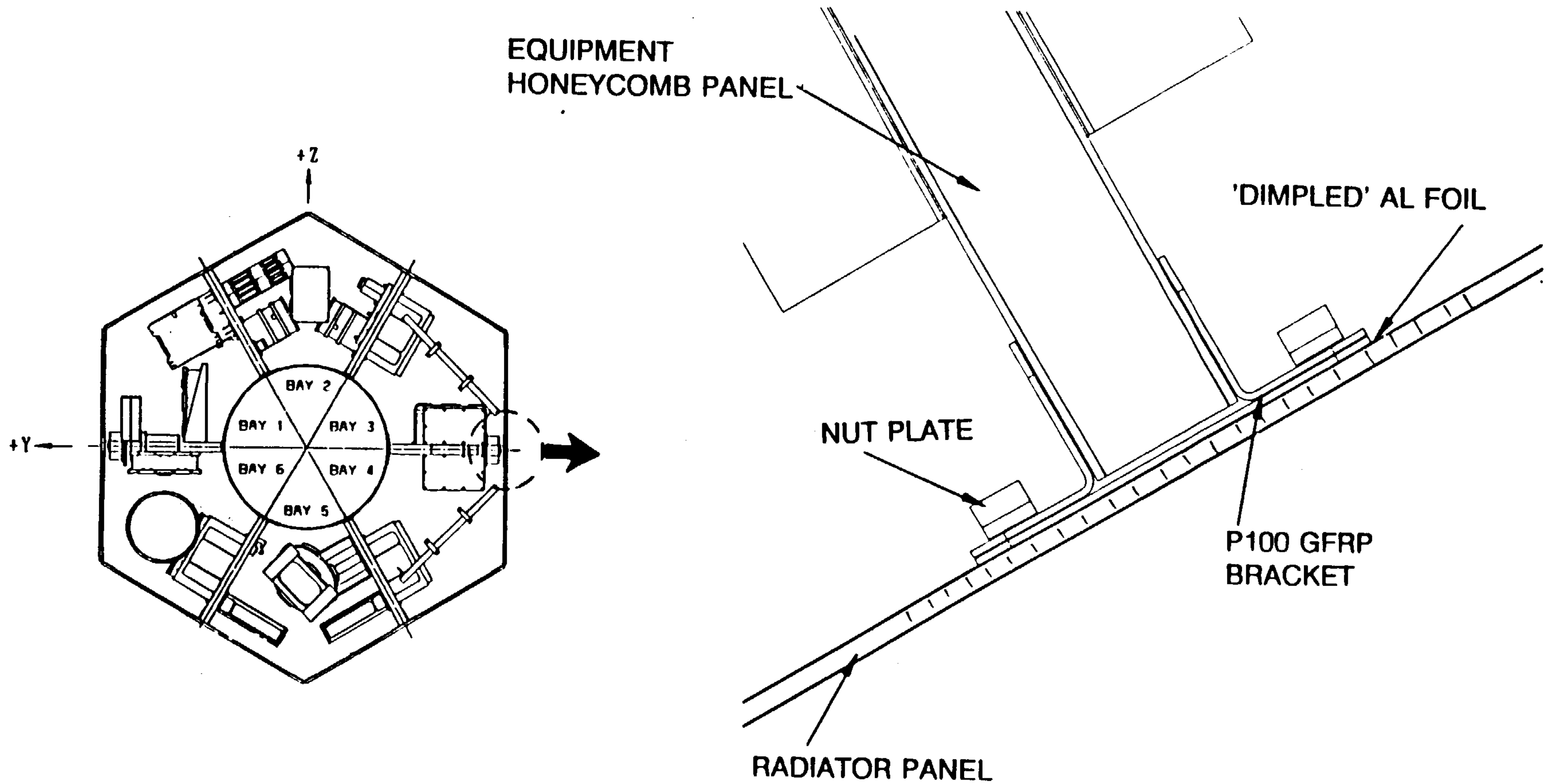
- High-emittance coating on electronic boxes and module interior surfaces
- 'Dimpled' aluminum foil between boxes and panels with optional use of plastic (RTV) interfaces
- Equipment mounted on high-conductivity interior panels
- Interior panels conductively coupled to rigid, high-conductivity exterior radiator panels
- High-dissipation equipment mounted on module anti-sun sides
- Exterior radiative capacity of panels adjustable by varying ratio of Z93-painted to MLI-blanketed surface areas. Second-surface Kapton MLI outer layer
- High-thermal impedance between modules
- Thermostatically controlled heaters



Equipment Panel-to-Radiator Interface Concept

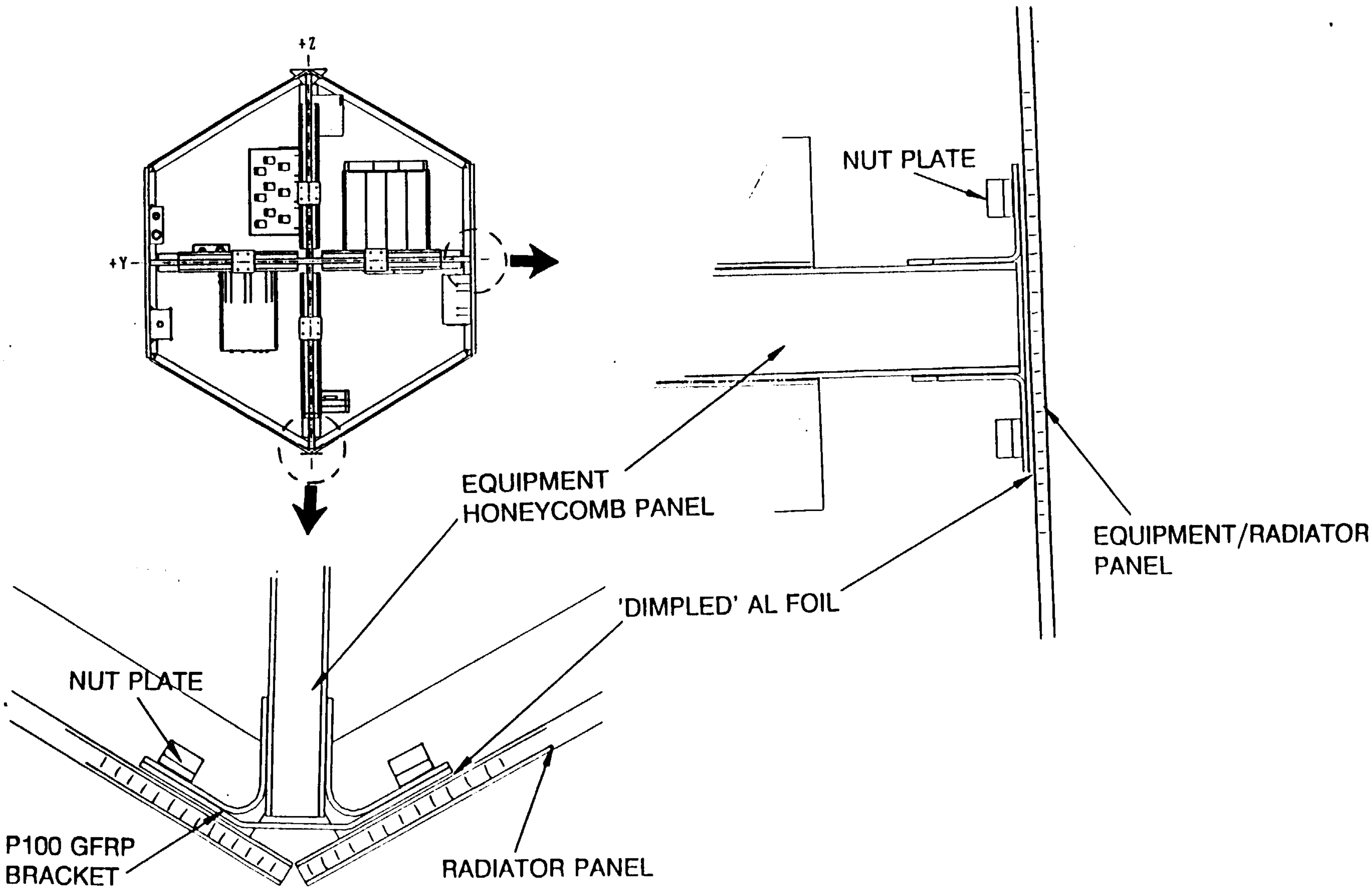


Key Avionics Module Thermal Interfaces

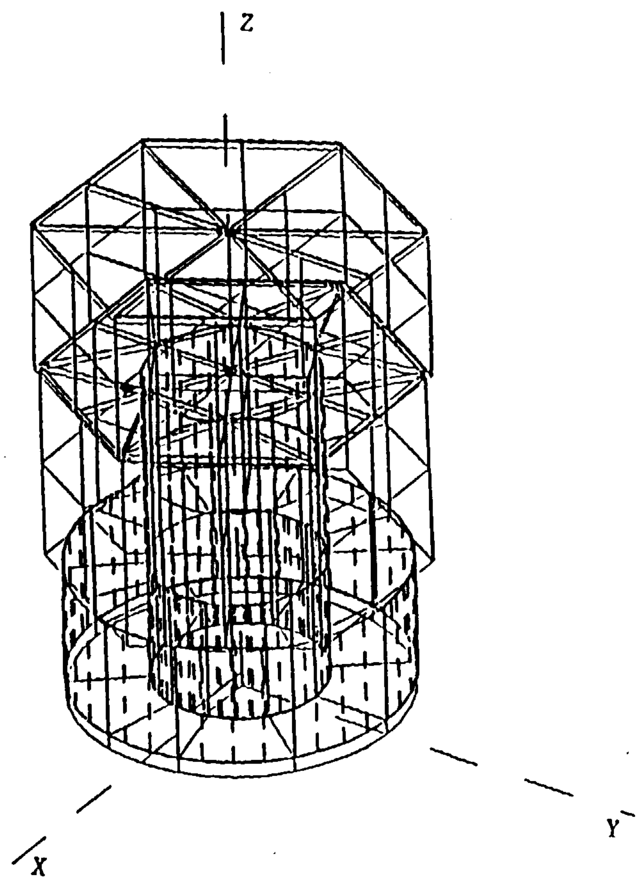


SSTI

Key Payload Module Thermal Interfaces

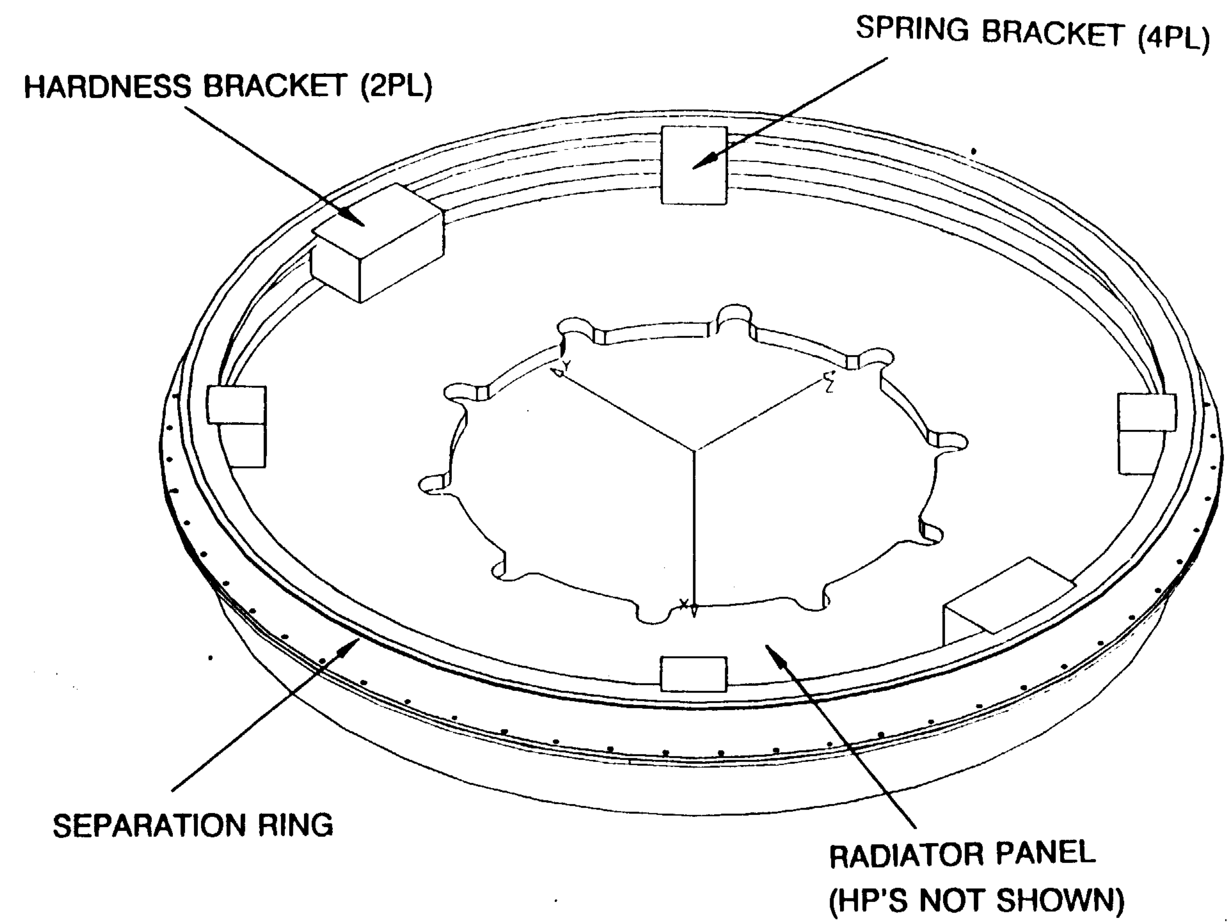


BPM, AM and PM Thermal Models



- Thermal Model Formatted for SINDA
- Surface Model Formatted for TRASYS II
- 550 Diffusion Nodes
- 340 Arithmetic Nodes
- 1700 Linear Conductors
- 6000 Radiative Conductors

Model of Spacecraft Aft Bulkhead Separation Appendages



Progress Since ICDA

- o Updated solar array thermal model and computed orbital heat loads from solar array on bus external surfaces
- o Incorporated new AM and PM equipment layout into bus thermal model
- o Updated equipment thermal masss, footprint surface area and heat dissipation
- o Perform evaluation of optical coatings, including paints and Ge-coated Kapton, for back side of solar array to support weight-vs-power trades
- o Formulated new bus insulation blanket design pattern and computed orbital temperatures using End-of-Life optical properties for solar beta angle of 17.4 degrees

Current Design of Z93-painted Radiator Panels

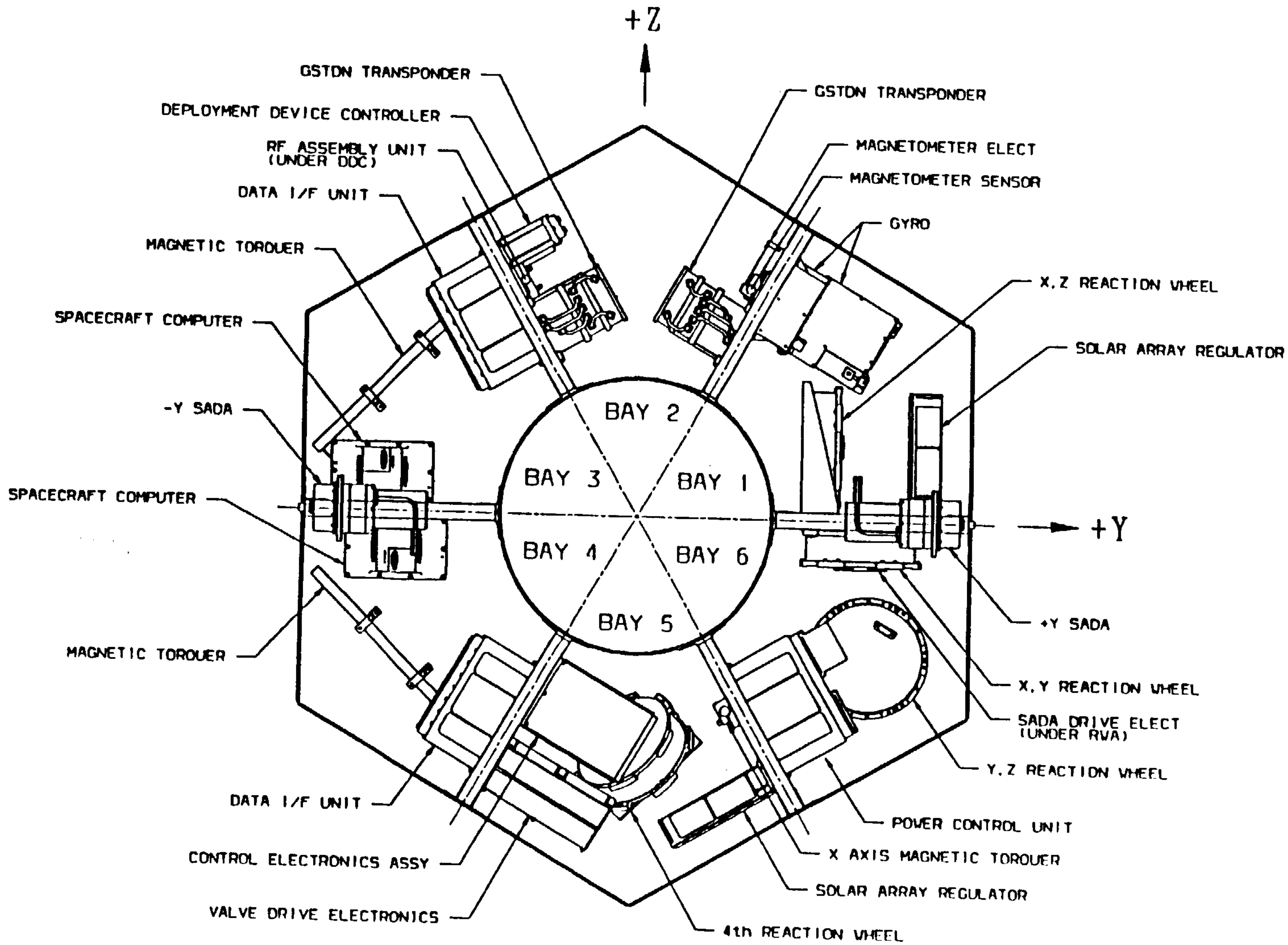
a. Avionics Module

Location	Percent MLI Coverage	Percent Radiator Area Used
+Z / -Y	75	25
-Y	0	100
-Z / -Y	75	25
-Z / +Y	75	25
+Y	75	25
+Y / +Z	75	25

b. Payload Module

Location		
+Z / -Y	50	50
-Y	50	50
-Z / -Y	50	50
-Z / +Y	50	50
+Y	25	75
+Y / +Z	50	50

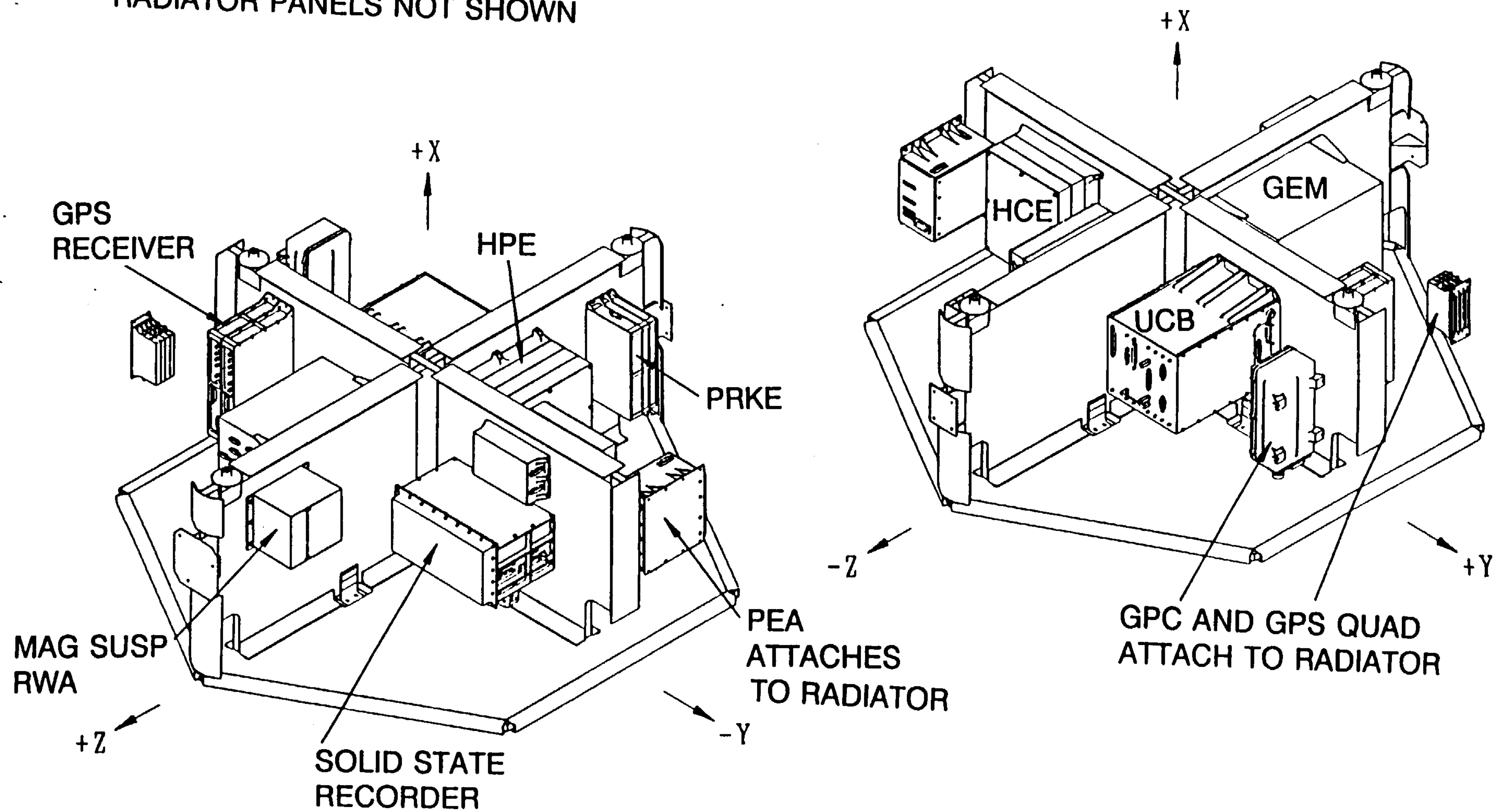
Bus Avionics Module Layout



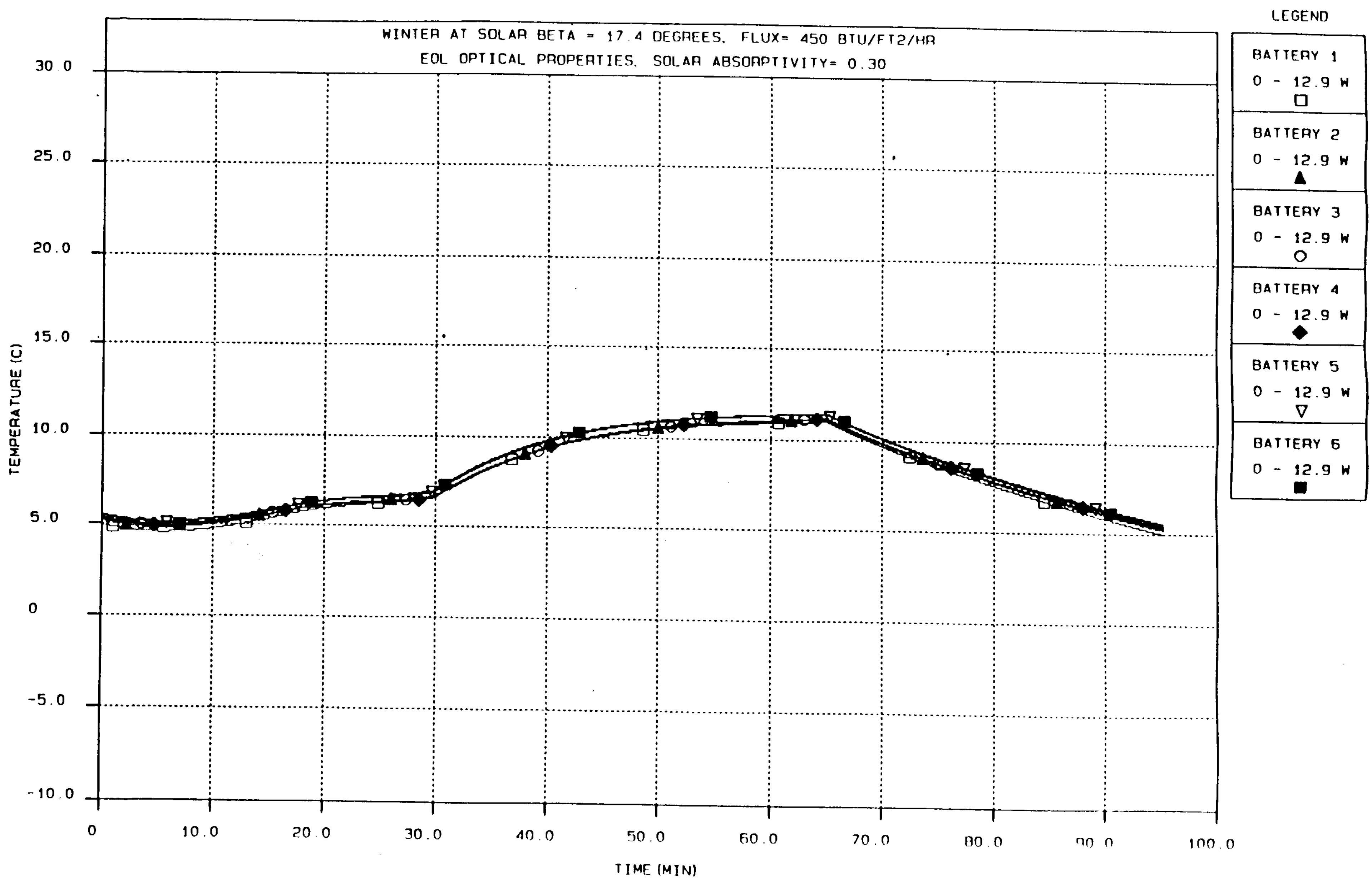
VIEW LOOKING -X

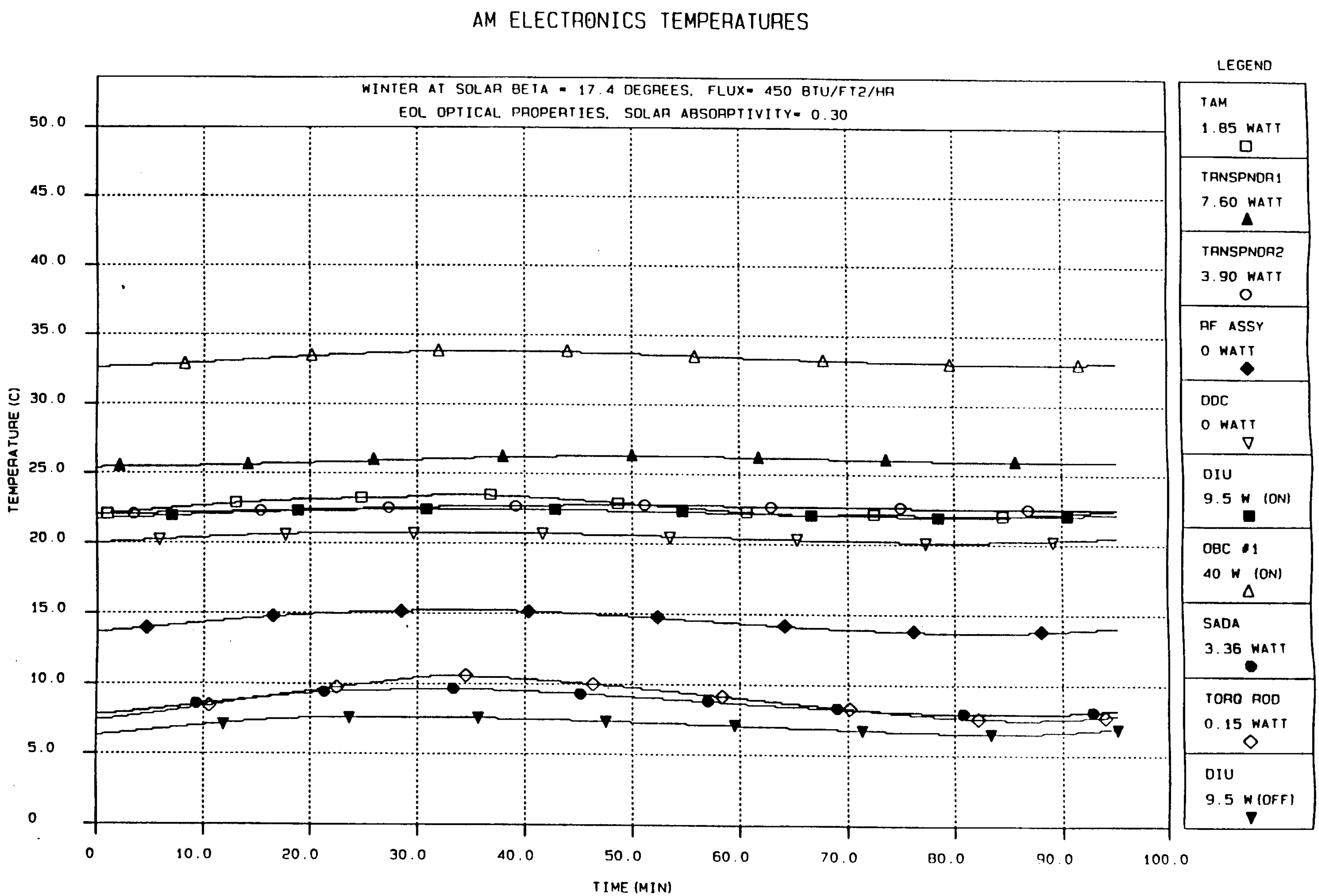
Bus Payload Module Layout

RADIATOR PANELS NOT SHOWN

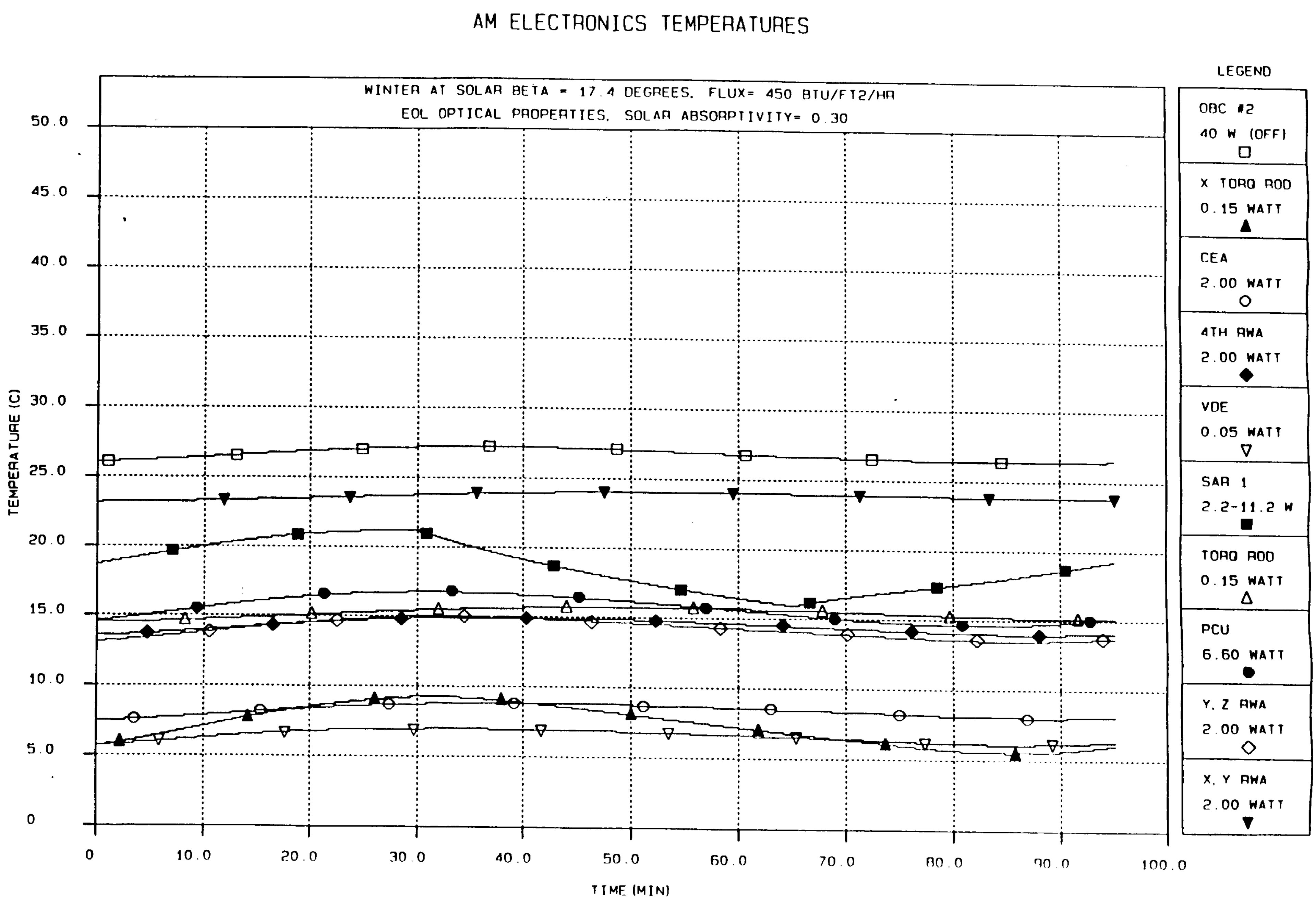


BPM BATTERY TEMPERATURES

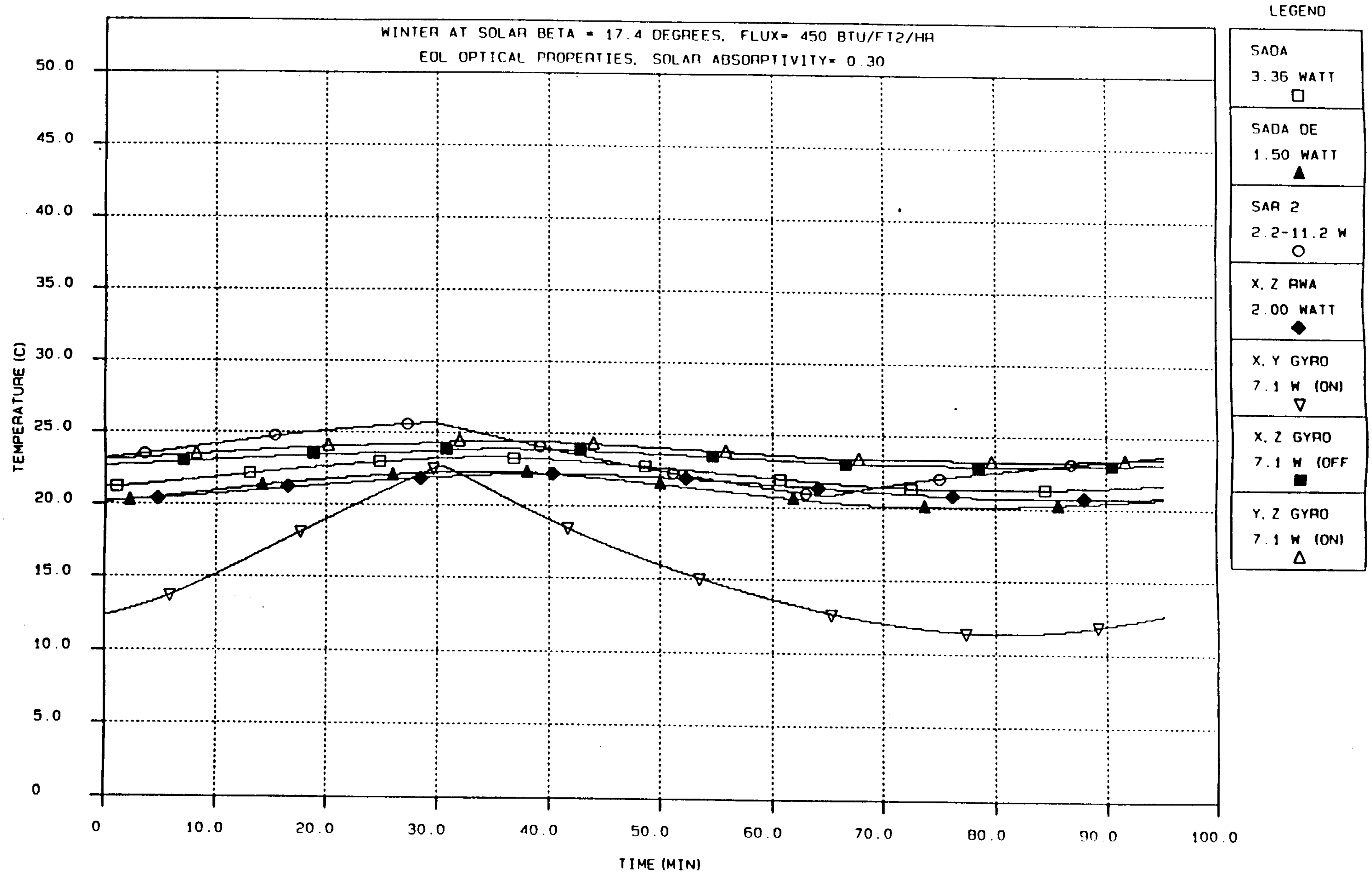


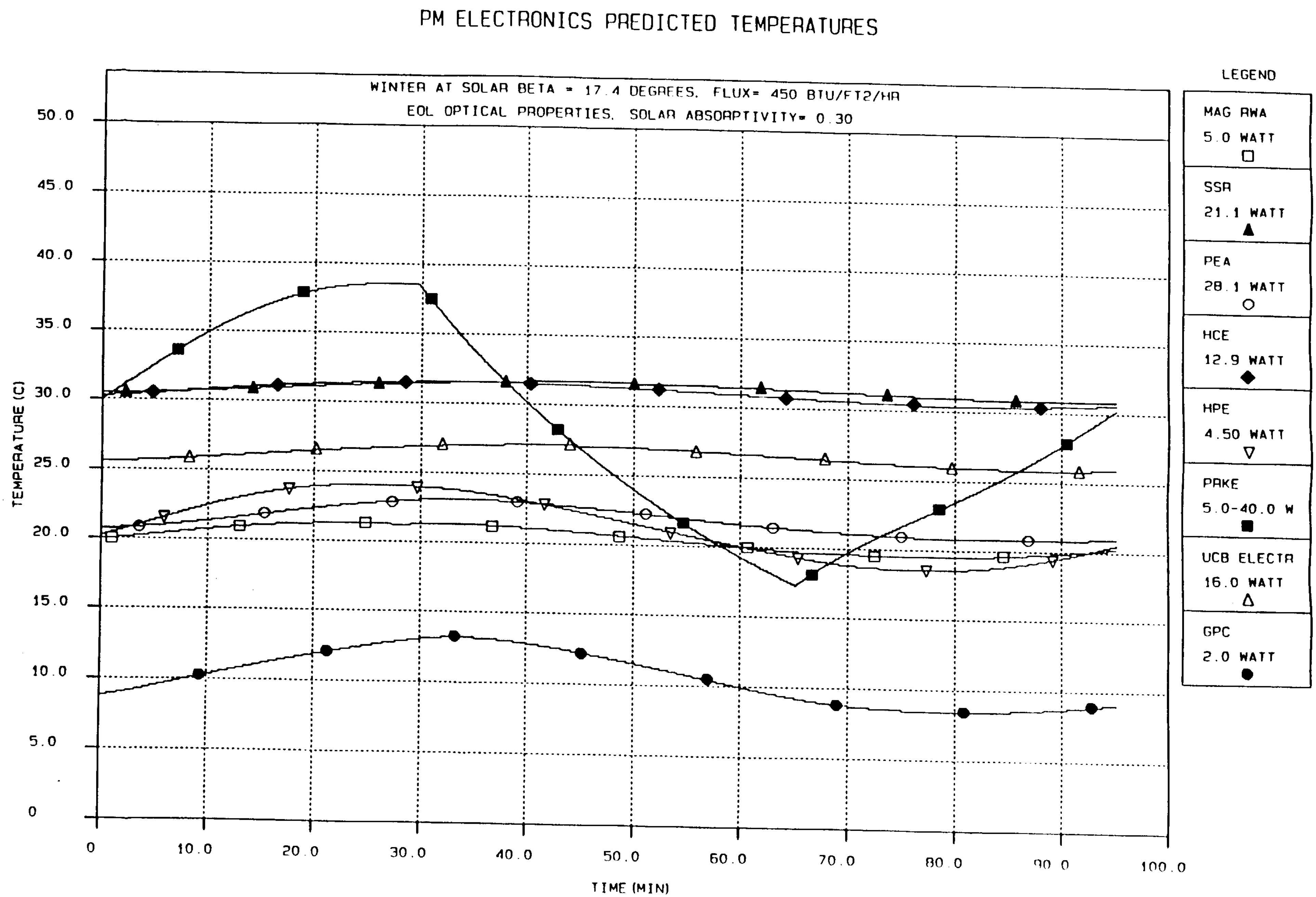


AM ELECTRONICS TEMPERATURES
WINTER AT SOLAR BETA = 17.4 DEGREES, FLUX= 450 BTU/FT2/HR
EOL OPTICAL PROPERTIES, SOLAR ABSORPTIVITY= 0.30
TEMPERATURE (C)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
TIME (MIN)
LEGEND
TAM
1.85 WATT
TRNSPNDR1
7.60 WATT
TRNSPNDR2
3.90 WATT
RF ASSY
0 WATT
DDC
0 WATT
DIU
9.5 W (ON)
OBC #1
40 W (ON)
SADA
3.36 WATT
TORQ ROD
0.15 WATT
DIU
9.5 W (OFF)

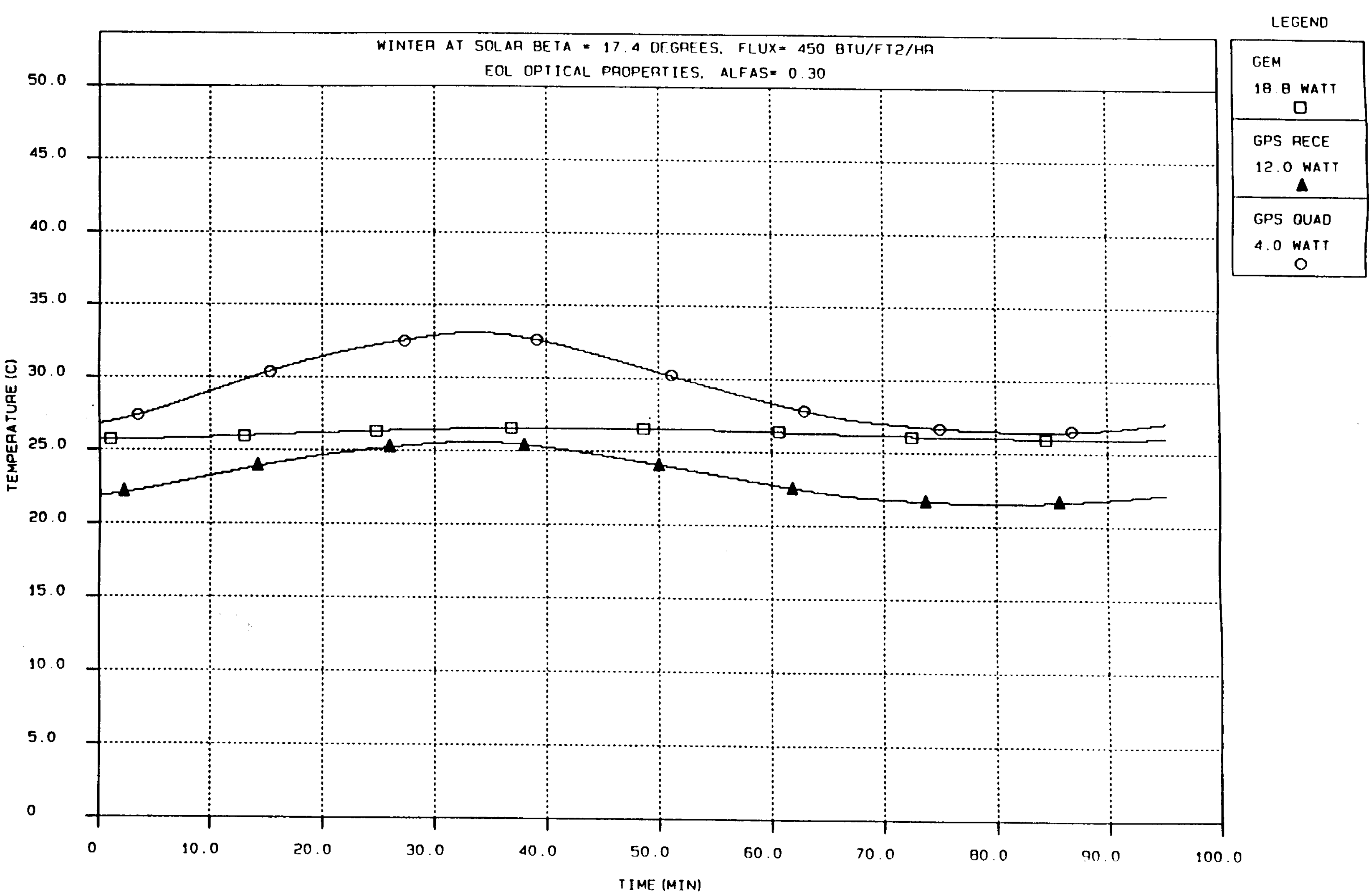

AM ELECTRONICS TEMPERATURES
WINTER AT SOLAR BETA = 17.4 DEGREES. FLUX= 450 BTU/FT2/HR
EOL OPTICAL PROPERTIES. SOLAR ABSORPTIVITY= 0.30
TEMPERATURE (C)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
TIME (MIN)
LEGEND
OBC #2 40 W (OFF)
X TORQ ROD 0.15 WATT
CEA 2.00 WATT
4TH RWA 2.00 WATT
VDE 0.05 WATT
SAR 1 2.2-11.2 W
TORQ ROD 0.15 WATT
PCU 6.60 WATT
Y, Z RWA 2.00 WATT
X, Y RWA 2.00 WATT

AM ELECTRONICS TEMPERATURES




PM ELECTRONICS PREDICTED TEMPERATURES
WINTER AT SOLAR BETA = 17.4 DEGREES, FLUX= 450 BTU/FT2/HR
EOL OPTICAL PROPERTIES, SOLAR ABSORPTIVITY= 0.30
TEMPERATURE (C)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0
0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
TIME (MIN)
LEGEND
MAG RWA 5.0 WATT
SSR 21.1 WATT
PEA 28.1 WATT
HCE 12.9 WATT
HPE 4.50 WATT
PRKE 5.0-40.0 W
UCB ELECTR 16.0 WATT
GPC 2.0 WATT

PM ELECTRONICS PREDICTED TEMPERATURES



Component Temperature Predictions

Subsystem	Unit	Acceptance Temp (°C)		Prediction (°C)		Margin (°C)	
		Min	Max	Min	Max	Min	Max
Guidance	GRA	5	55	(A)	24	(A)	31
	TAM	-20	55				
	Coarse Sun Sensor	-115	95				
	Earth Sensor	-5	55				
	RWA	-5	50	(A)	24	(A)	26
	CEA	-20	55	(A)	10	(A)	45
	Torque Rods	-20	55	(A)	16	(A)	39
	VDE	-20	55	(A)	8	(A)	37
	SADA	-24	61	(A)	24	(A)	37
	SADE	-24	61	(A)	23	(A)	38
	NFOV Star Tracker	-5	45				
Data Management	S/C Computer	-24	61	(A)	28	(A)	33
	DIU	-24	61	(A)	23	(A)	38
	Transponder Transmitter	-20	55	(A)	27	(A)	28
	Transponder Receiver	-20	55	(A)	23	(A)	32

Component Temperature Predictions - Continued

Subsystem	Unit	Acceptance Temp (°C)		Prediction (°C)		Margin (°C)	
		Min	Max	Min	Max	Min	Max
Electrical Power	PCU	-10	28	(A)	17	(A)	11
	DDC	-20	35	(A)	21	(A)	14
	SAR	-20	45	(A)	27	(A)	18
	Battery (Recharge)	0	25	0	12	(B)	13
	Solar Array	-90	82	-73	60	17	22
Tech Demo	GEM SLAM	-24	61	(A)	27	(A)	34
	GEM GPS	-24	61	(A)	26	(A)	35
	GEM Solar Cell	-90	82				
	Solar Cells	-90	82				
	Reaction Wheel	0	60	(A)	22	(A)	38
	GPC (Rad Monitor)	-10	55	(A)	14	(A)	41
	WFOV Star Tracker	-5	45				

Notes:

(A): Worst-cold case analysis in progress; predictions will be provided at next IPT

(B): Minimun acceptance temperature requirement met with 12-Watt thermostatically controlled heater

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Component Temperature Predictions - Continued

Subsystem	Unit	Acceptance Temp (°C)		Prediction (°C)		Margin (°C)	
		Min	Max	Min	Max	Min	Max
Payload Support	UCB	-15	45	(A)	27	(A)	18
	SS Recorder	-24	61	(A)	32	(A)	29
	HCE and HPE	-20	60	(A)	32	(A)	28
	PRKE	-20	60	(A)	39	(A)	21
	PEA	-24	61	(A)	23	(A)	38

Thermal Control Design Test Verification

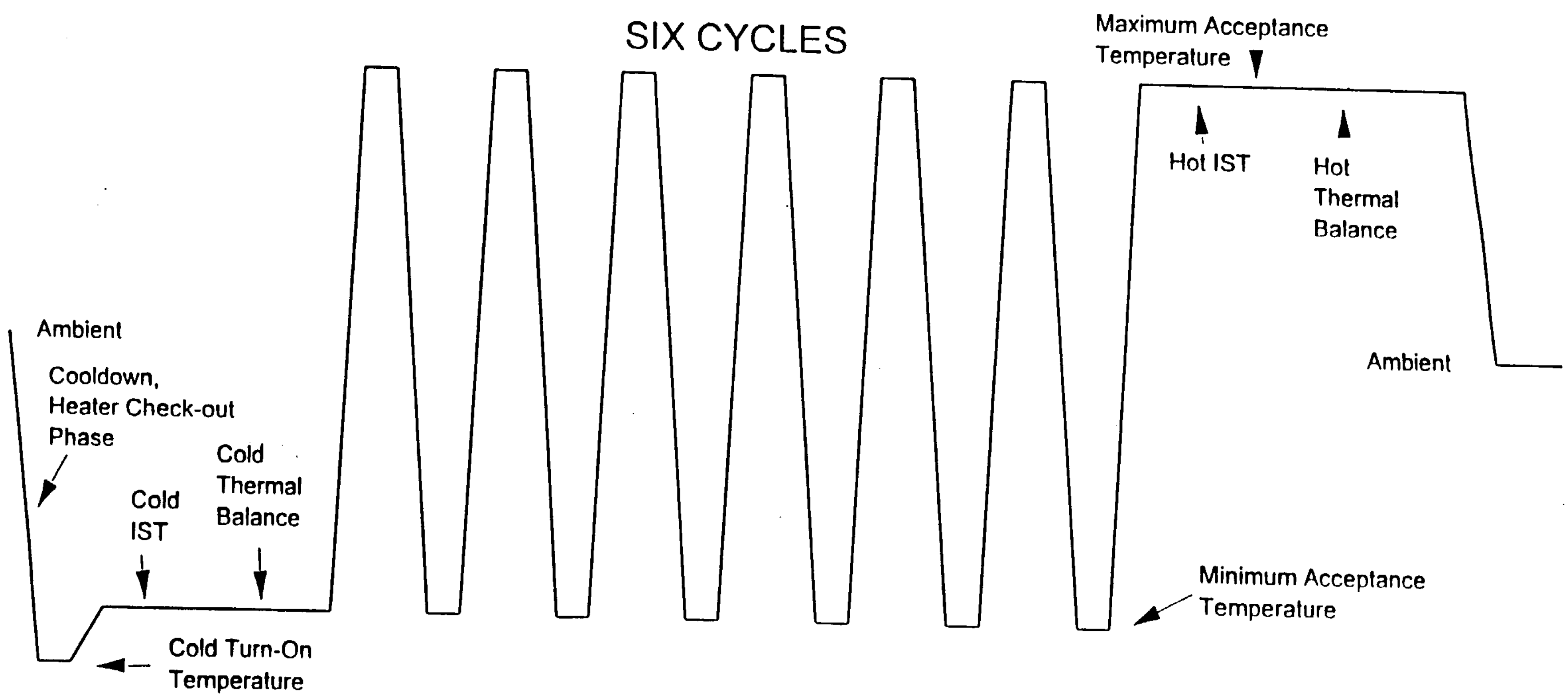
I. Electronic box-to-panel and equipment panel-to-radiator interface conductances

- two representative boxes selected
- aluminum boxes attached to composite panels using RTV and dimpled aluminum foil
- composite radiator panels attached to composite equipment panels using RTV and dimpled aluminum foil
- test articles subjected to thermal cycling in vacuum and vibration
- thermal conductance measured before and after thermal cycling and vibration
- objectives are to quantify conductance and assess repeatability

II. Spacecraft bus thermal vacuum test approach

- LN2-cooled shroud in chamber simulates deep space environment
- estimated absorbed environmental heating on AM and PM radiators simulated using tape heaters attached to interior surfaces of radiator panels
- conductive heat leakeages from Solar Array Drive Assemblies will be simulated using temperature-controlled dummy boom/yoke design

Spacecraft Thermal Vacuum Test



Environmental heating will be simulated with heaters installed on inner facesheets of outer panels.

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Close-out Tasks

- Coordinate thermal K1100 requirements with structural design
- Review cold temperature operation
  - o Analyze for "worst case" cold power dissipation
- Size and locate heater and thermostats
- Analyze launch/ascent scenario
  - o Determine S/C performance
  - o Establish thermal launch constraints, if needed
- Verify by test the performance of interface foil through temperature cycling and vibration
- Optimize MLI attachment methods

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TRW

SSTI Program CDA
Orbit Adjust Subsystem (OAS)

19 January 1995

G. W. Joseph

SSTI

Propulsion System Features

- Monopropellant Hydrazine blowdown system
- Blends qualified flight proven components with new technology demonstration
  - TDRS MRE-1 thrusters
  - Flight qualified valves, filter and transducer
  - New technology Graphite/Epoxy overwrap propellant tank
- Provides impulse for orbit transfer, maneuvers, safe haven mode and back-up attitude control
- Simple blowdown operation reduces risk and ground station requirements
- All welded system for safety compliance and reliability
- Thrusters located aft for propellant settling, minimizes plume impingement and contamination

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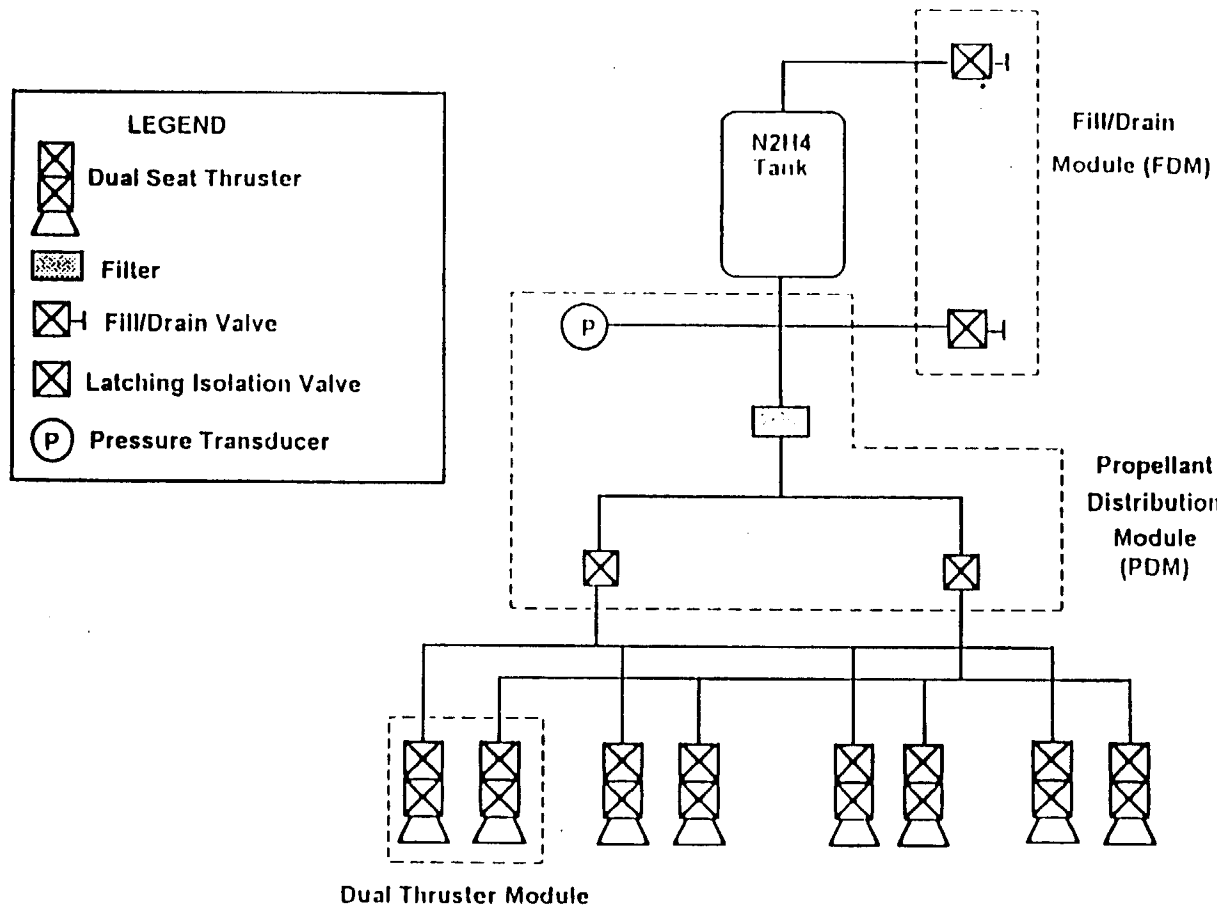
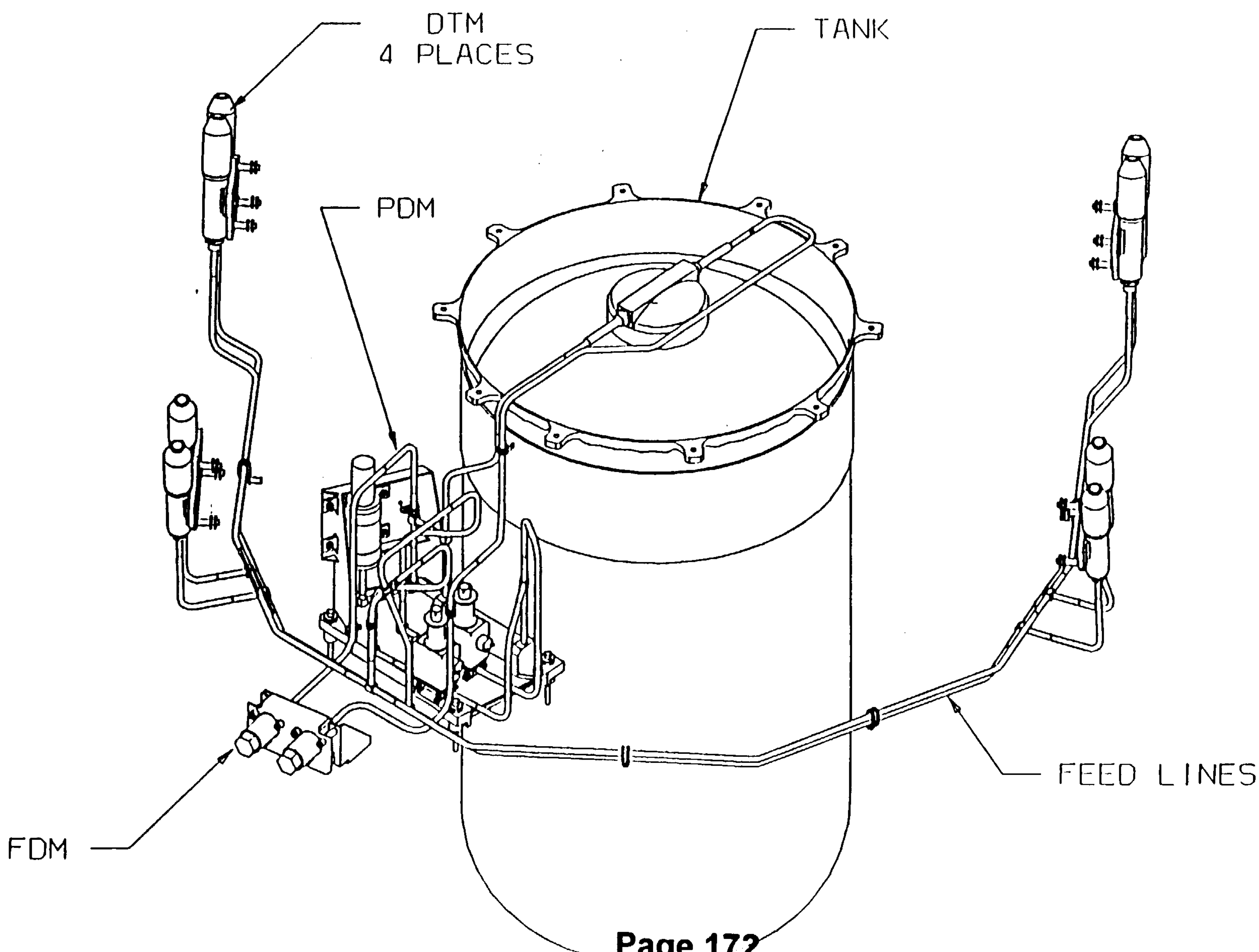
Propulsion System Features (cont.)

- Reduced number of components to minimize cost and schedule
- Two fault tolerant to catastrophic leakage, ground and launch
- At least single fault tolerant during all operational modes
- Modular design allows parallel assembly of major modules with structure, ready for I&T upon structure delivery
  - Propellant Distribution Module
  - Fill and Drain Module
  - Dual Thruster Module
  - Propellant Tank Assembly
  - Maximum propellant capability of 80.4 Kg at 4:1 blowdown

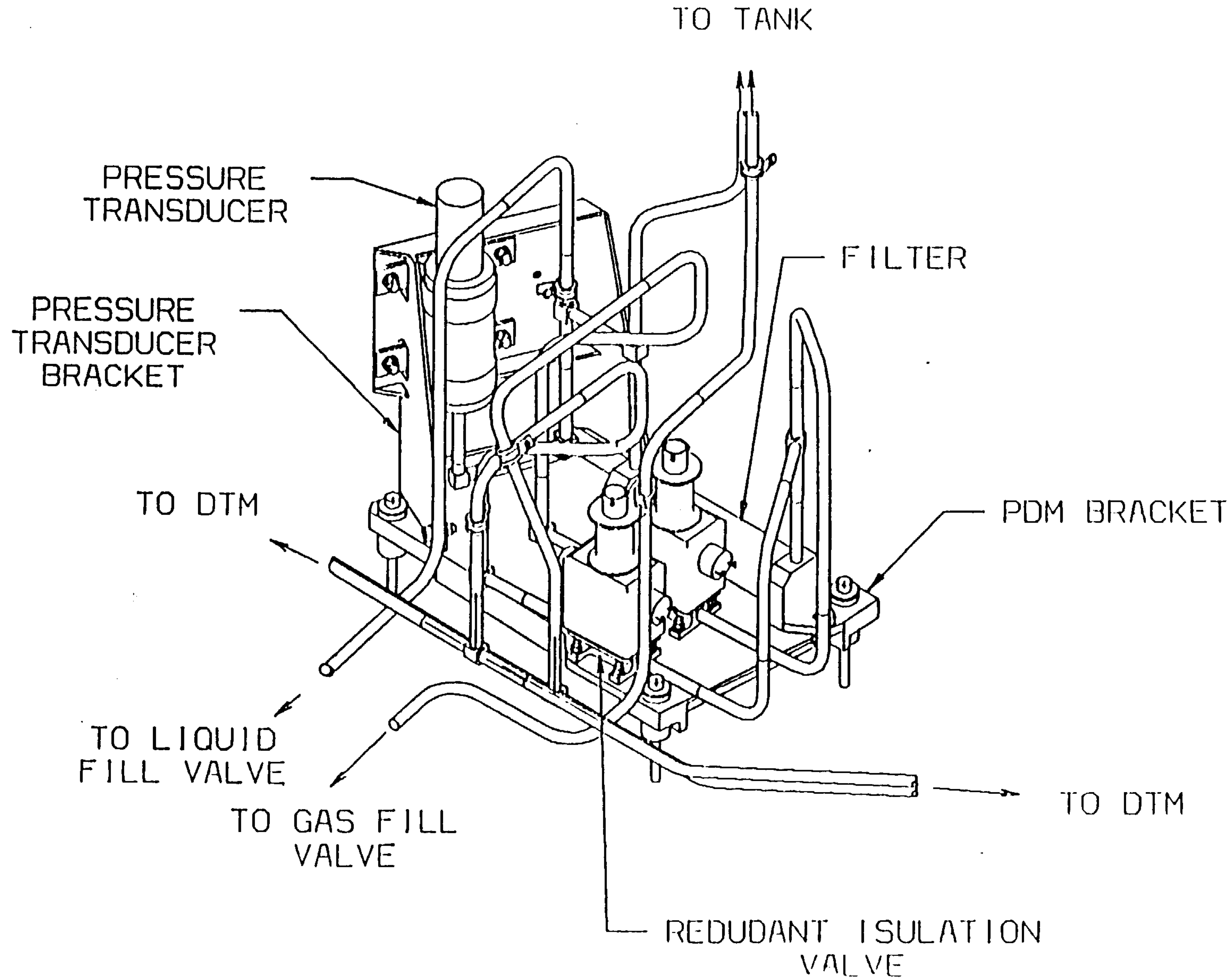
OAS Schematic



OAS Aft View



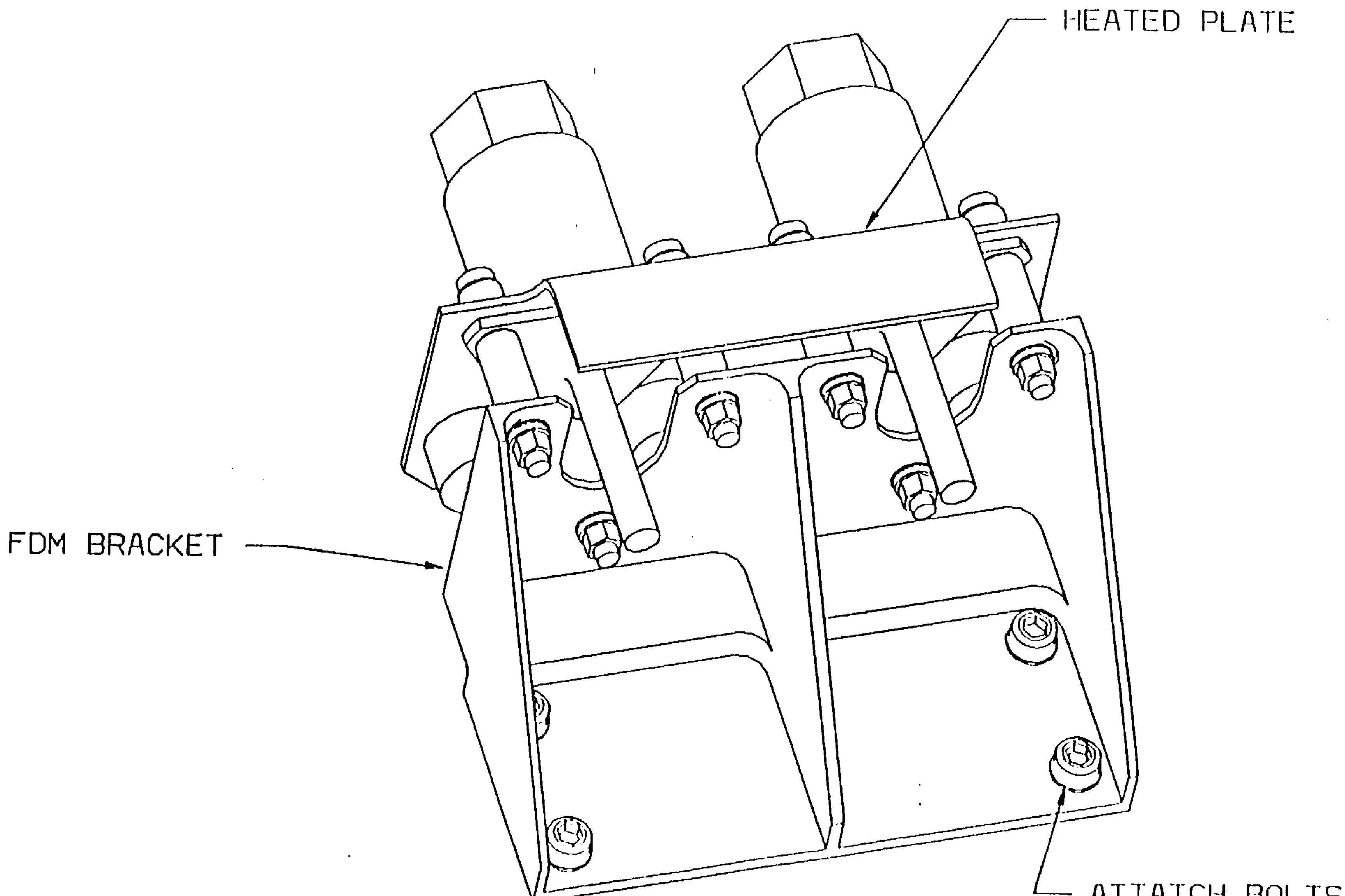
Propellant Distribution Module (PDM)



SSTI

Fill and Drain Valve Module (FDM)

TRW



Propellant Tank Description

- **MATERIALS:** 0.010-INCH-THICK 6061 SEAMLESS ALUMINUM LINER OVERWRAPPED WITH T-1000 GB GRAPHITE/EPOXY COMPOSITE, SKIRT IS IM-6/3501-6 GRAPHITE/EPOXY WITH A 7075-T7351 ALUMINUM MOUNTING RING
- **SIZE:** 17-INCH DIAMETER BY 33.75-INCH LENGTH
- **SHAPE:** CYLINDRICAL WITH ESSENTIALLY 0.69 ELLIPSOIDAL HEADS
- **PRESSURES:** MAX. DESIGN PRESSURE = 500 PSID, PROOF = 625 PSID, BURST ≥ 750 PSID
- **MAXIMUM WEIGHT:** 15 LBm
- **EXPULSION:** SINGLE INLET/OUTLET BOSS USING PROPELLANT SETTLING-SURFACE-TENSION-TYPE PROPELLANT MANAGEMENT DEVICE PREVENTS GAS INGESTION
- **LOAD:** 232 LBm OF HYDRAZINE (MAXIMUM)

SSTI

Propellant Tank Heritage

TRW

- ERIS BI-PROPELLANT TANKS
    - FOUR HAVE FLOWN - ALL SUCCESSFULLY
    - GRAPHITE/EPOXY OVERWRAP WITH 0.020-INCH-THICK ALUMINUM LINERS
    - 4.8-INCH DIAMETER BY 13.8-INCH LENGTH
    - 1000-PSID MAXIMUM DESIGN PRESSURE, 4000-PSID BURST PRESSURE
- PEGASUS HYDRAZINE TANK
    - TWO HAVE FLOWN - BOTH SUCCESSFULLY
    - GRAPHITE/EPOXY OVERWRAP WITH 0.065-INCH-MINIMUM-THICKNESS 6061 ALUMINUM LINERS

SSTI

Propellant Tank Heritage (cont.)

- PEGASUS HYDRAZINE TANK (CONT'D.)
  - 19.7-INCH DIAMETER BY 23.9-INCH LENGTH
  - 464-PSID MAXIMUM DESIGN PRESSURE, 696-PSID MINIMUM BURST PRESSURE
- AB 600 PROPELLANT TANK
  - SSTI TANK IDENTICAL TO AB 600 QUALIFICATION UNIT
  - TWO DEVELOPMENT TANKS BUILT AND SUCCESSFULLY TESTED TO DATE - ONE DVT TANK HAD 0.010 INCH THICK LINER

SSTI

Propellant Tank Qualification Plan

- BUILD AND TEST TWO DEVELOPMENT TANKS AND ONE FORMAL QUALIFICATION TANK
  - DVT 001 (0.030-INCH-THICK LINER) (COMPLETED)
    - AUTOFRETTAGE (SIZING) PRESSURE - 625 PSID
    - LEAK TEST - 500 PSID
    - PROOF TEST - 625 PSID
    - LEAK TEST
    - SKIRT PROOF TEST
    - PRESSURE CYCLE TEST - 16 PROOF CYCLES, 36 OPERATING CYCLES

Propellant Tank Qualification Plan

- PROTOFLIGHT - LEVEL VIBRATION TESTING ON AB 600 STRUCTURE
- BURST PRESSURE TEST TO 750 PSID - NO RUPTURE

- DVT 002 (0.010-INCH-THICK LINER) (COMPLETED)
  - AUTOFRETTAGE - 625 PSID
  - LEAK TEST - 500 PSID
  - PRESSURE CYCLE TEST
  - BURST PRESSURE TEST TO 750 PSID - NO RUPTURE
  - LEAK TEST

SSTI

Propellant Tank Qualification Plan

- FORMAL QUALIFICATION UNIT (Q001) COMPLETION BY 3-1-94)
  - IN-PROCESS QUALIFICATIONS (WELD QUAL, SPIN-FORMING QUAL, ETC.)
  - AUTOFRETTAGE
  - LEAK TEST
  - SKIRT PROOF TEST
  - PROOF TEST
  - LEAK TEST
  - PRESSURE-CYCLE TEST
  - RANDOM VIBRATION TO QUALIFICATION LEVELS (TWO AXES)
  - ACCELERATION TEST TO QUALIFICATION LEVELS (TWO AXES)
  - LEAK TEST

Propellant Tank Qualification Plan

- BURST TEST TO 750 PSID, THEN INCREASE TO RUPTURE
- EXPULSION QUALIFICATION BY ANALYSIS
- FRACTURE CONTROL QUALIFICATION BY TEST SAMPLES
  - FRACTURE CONTROL
  - FRACTURE CONTROL TASK IS TO VERIFY THAT LINER WILL NOT LEAK IN FOUR MISSION DUTY CYCLES
  - FOUR ELEMENTS OF FRACTURE CONTROL
  - STRESS ANALYSIS
  - NON-DESTRUCTIVE INSPECTION FOR CRACKS
  - FRACTURE MECHANICS MATERIAL PROPERTIES
  - STRESS INTENSITY FACTOR SOLUTION

SSTI

OAS Operation

- Isolation valves remain open throughout mission
- Redundant thrusters catalyst bed heaters remain on at one third power (one of three heaters on) for use if safe haven mode needed
- Primary thrusters catalyst bed heaters turned on prior to planned maneuvers
- System operates in pure blowdown mode from 365 psia @70F to 225 psia @60F
- All thrusters oriented aft precludes need for propellant management device other than vortex suppresser
- Passive and active (thermostat controlled) heaters maintain safe temperature without ground intervention
- Once on orbit, OAS requires no active maintenance. Monitor for anomalous conditions only

OAS Thermal Control

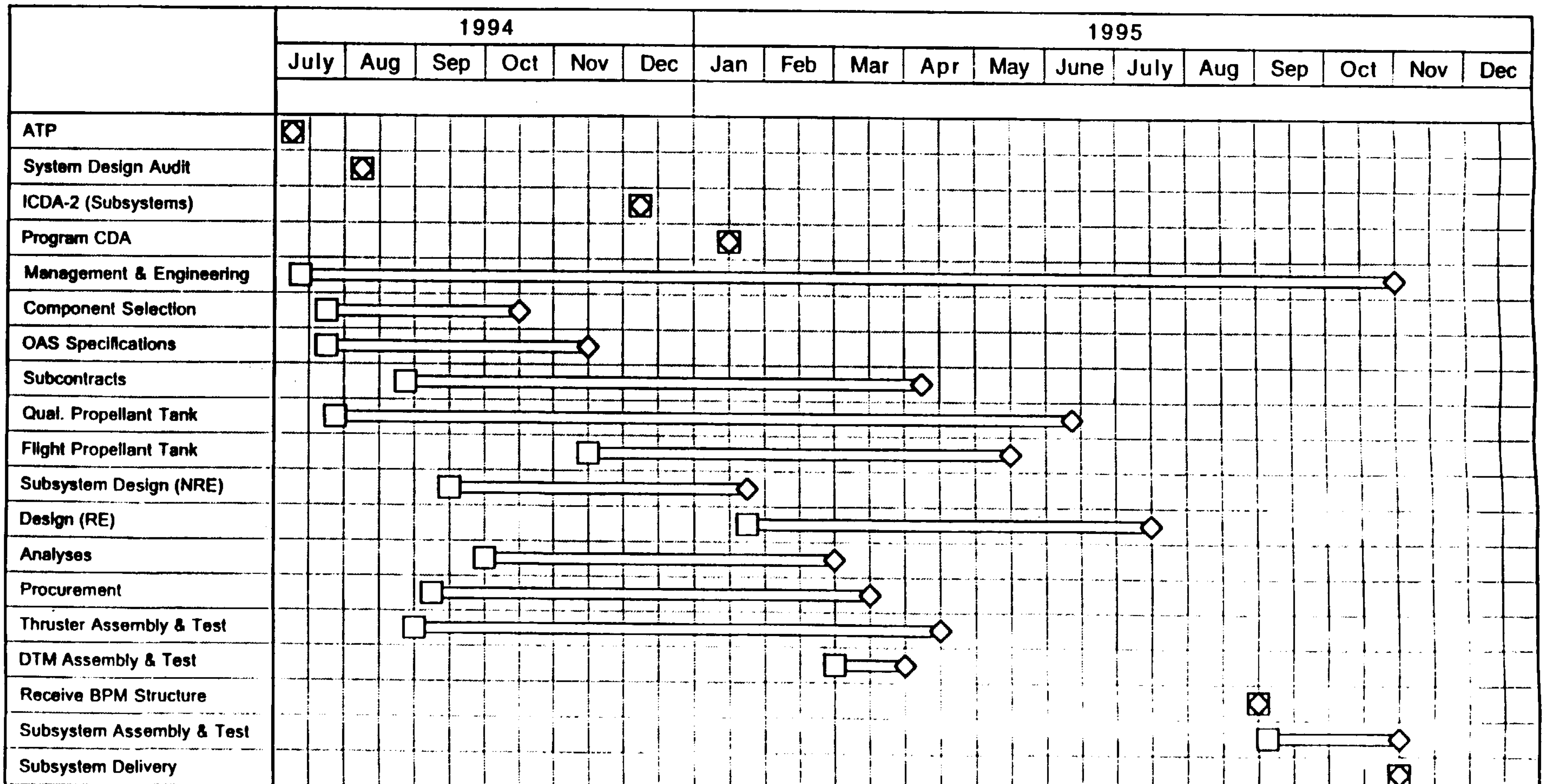
- Propellant tank and all lines and components heated, controlled with thermostats
- Each module and lines have both primary and redundant heaters with series redundant thermostats
- FDM, PDM, tank are enclosed in MLI thermal blankets
- DTMs use aluminum enclosure similar to TDRS
- PDM,FDM and DTMs are heated as modules to reduce heater power and thermal transients
- Line heaters are coiled wire elements in kapton insulation secured to lines with aluminum tape
- Thermostats are bi-metallic switches hermetically sealed identical to TOMS, TDRS etc..

SSTI

OAS Schedule

TRW

- Detail schedule used to track OAS progress and report to P.O.



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OAS Status

- OAS detail schedule and baseline complete
- Thruster piece part procurement 90% complete
- All major component subcontractors selected and on order or already received (ICMT)
- System layout complete
- System module drawings; DTM, FDM, PDM 90% complete
- Line bend data drawing 70% complete
- Thermal and structural analyses on schedule with design progress
- Fluid dynamic analysis will start in January
- Subsystem specification 95% complete

OAS Requirements vs Capabilities

Paragraph/Requirement	Source	Capability	Verification
3.1.1 General Description Orbit Adjust Subsystem (OAS) provides impulse for orbit transfer and attitude control of SSTI spacecraft. Impulse provided by catalytic decomposition of monopropellant grade hydrazine stored in a propellant tank and supplied to thrusters in a blowdown pressurization mode. Eight 4.45 N (1-lbf) thrusters (MRE-1) used for attitude control and delta-V Thrusters configured in dual thruster modules (DTM) with one primary and one redundant thruster	SS3-055 SSTI OAS Specification	Complies.	N/A
3.1.2 Subsystem Configuration OAS major subassemblies and components defined in Table 3-1.	SS3-055 SSTI OAS Specification	Complies	Inspection
3.1.3.1 Propellant Tank Cylindrical shape tank with ellipsoidal heads Graphite overwrap design with aluminum liner Diameter = 17 in Length = 33 in Surface tension type propellant management device (PMD) MOP = 500 psia, burst factor of safety = 1.5 Operates in blowdown mode Propellant Load = TBD lbm	SS3-055 SSTI OAS Specification	Complies. Cylindrical aluminum liner with elliptical end domes overwrapped with epoxy resin impregnated carbon fiber. Integral mounting skirt provided. Aluminum outlet cap/PMD assembly Maximum propellant load capability = 232 lbm (1% ullage)	N/A
3.1.3.2 Fill and Drain Valves Provide interface for OAS verification tests and ground loading of propellant and pressurant. Inner cap and outer cap provided as redundant seals (three total, two soft seals and one metal to metal).	SS3-055 SSTI OAS Specification	Complies. Permits loading and unloading of propellant and pressurant gas, pressurization and venting of system during ground testing and loading. Primary seal is metal-to-metal. Secondary seal is inner cap and O-ring (in parallel). Third seal is outer cap with O-ring.	N/A

Paragraph/Requirement	Source	Capability	Verification
3.1.3.3 Pressure Transducer Measures propellant supply pressures. 0 to 5 Vdc output corresponding to 0 to 41.4 Bar (0 to 600 psia), electrical signal will be produced for relay to the ground.	SS3-055 SSTI OAS Specification	Complies. Machined diaphragm with thin-film vacuum deposited strain gauges and electronics for signal conditioning and amplification. Maximum operating pressure = 585 psig	N/A
3.1.3.4 Filter Located in outlet line from propellant tank to protect OAS components from contamination. Filtration rating = 10 microns absolute	SS3-055 SSTI OAS Specification	Complies. Woven wire mesh with internal support element. Filtration rating = 10 microns absolute	N/A
3.1.3.5 Dual Thruster Module (DTM) Assembly Four DTM assemblies total. Each DTM consists of one primary and one redundant MRE-1 thruster. Each thruster contains one dual seat/dual coil valve.	SS3-055 SSTI OAS Specification	Complies. Series-redundant solenoid valve assembly with two sets of seals and coils. Maximum valve back pressure relief = 500 psid.	N/A
3.1.3.6 Latching Isolation Valves Protect OAS integrity against failed open or excessive internal leakage. Contains an integral position indicator. Valve back pressure relieves if downstream pressure > 4~~2~~00 psi higher than upstream pressure.	SS3-055 SSTI OAS Specification	Complies. Isolates RCS thruster banks. Torque motor actuation with permanent magnetic latching. Integral position switch provides positive indication of poppet position. Maximum back pressure relief = 400 psid	N/A
3.1.4.1.1 Interfaces External to the Spacecraft Electrical Ground Support Equipment (EGSE) required to monitor subsystem status and to actuate isovalves and thruster valves during ground checkout, propellant/pressurant loading, and servicing. Parameters to be monitored will include: Propellant tank pressure Propellant tank temperature (ground-only temperature sensor)	SS3-055 SSTI OAS Specification	Complies	Analysis and inspection

OAS Requirements vs Capabilities

Paragraph/Requirement	Source	Capability	Verification
3.1.4.1.2.1 Electrical Power Internal OAS electrical interfaces defined in IF1-058, Electrical System Interface Specification. Heater and telemetry harnesses and valve power and return harnesses terminate at the OAS electrical connector per IF1-058. All other electrical cables furnished by spacecraft. Primary power quality, in-rush current, secondary power and grounding requirements defined in SR1-0125. Voltages supplied to OAS components listed in Table 3-2.	SS3-055 SSTI OAS Specification	Complies	Analysis and inspection
3.1.4.1.2.2 Thruster Valve Signals OAS thruster valves respond to signals from Valve Drive Electronics (VDE) with the following characteristics: On-state voltage: 23.0 to 38.6 Minimum electrical pulse width: 25 milliseconds Valve driver incorporates two 27V zener diodes in series to achieve 15.4 to 31.0 volts across valve coil.	SS3-055 SSTI OAS Specification	Complies	Test
3.1.4.1.2.3 Isolation Valve Signals Isolation valves open or close when supplied with 50 msec (minimum) to 1 second maximum pulse from VDE.	SS3-055 SSTI OAS Specification	Complies	Test
3.1.4.1.2.4 Commands Thruster valves, latching isolation valves, catalyst bed heaters, thruster valve heaters and other (tank, line and component module) heaters commanded from VDE, EIA, or RCTU relay boards as appropriate. All commands switch between 0 and primary bus voltage. Commands (primary and redundant) required to operate thrusters, latching isolation valves, pressure transducers, and heaters, exclusive of GN&C generated commands for VDE thruster firings, defined in SSTI Command Allocation Document D22884. All commands in the table shall be momentary (discrete).	SS3-055 SSTI OAS Specification	Complies	Analysis and inspection

OAS Requirements vs Capabilities

Paragraph/Requirement	Source	Capability	Verification
3.1.4.1.2.5 Telemetry Temperature and pressure sensors, heater status, and valve position indication telemetered for state-of-health evaluation and operations support. Bilevel status measurements derived from driving sources (VDE, EIA, or RCTU). Analog pressures or temperatures have 0 - 5 volt output and are measured using circuits in the EIA or RTCU.	SS3-055 SSTI OAS Specification	Complies	Analysis and inspection
3.1.4.2.1 Interfaces External to the Spacecraft Propellant and pressurant loaded and drained using Mechanical Ground Support Equipment (MGSE) supplied by spacecraft Integration and Test. MGSE includes Propellant and Pressurant Loading System (PPLS) and fueling standpipe. Fluids entering OAS filtered to 10 microns absolute. Fluid connections between loading cart and OAS made at fill and drain valves. MGSE includes handling fixture for transportation, assembly and test of OAS.	SS3-055 SSTI OAS Specification	Complies	Analysis and inspection
3.1.4.2.2.1 Structure Physical interfaces between OAS and SSTI spacecraft defined in TBD, Interface Control Drawing, Structure and Mechanisms Subsystem to Orbit Adjust Subsystem. OAS assembled onto the Battery/Propulsion Module (BPM).	SS3-055 SSTI OAS Specification	Complies	Inspection
3.1.4.2.2.2 Thruster Locations and Orientations Thruster locations and orientations on the SSTI spacecraft defined in ICD TBD. Thruster orientation during transportation and launch: catalyst bed positioned below thruster injector, (or at same elevation) to preclude catalyst particles from migrating into injector.	SS3-055 SSTI OAS Specification	Complies	Inspection
3.1.4.2.2.3 Alignment Nozzle axes of the thrusters on each DTM shall be parallel to each other within 1.5 degrees. Primary thruster of each DTM aligned on spacecraft subsequent to delivery of OAS. DTM capable of providing spacecraft thrust vector alignment with 3 hard mounting points and adjustable by shimming.	SS3-055 SSTI OAS Specification	Complies	Test (OAS and spacecraft level)

SSTI

OAS Requirements vs Capabilities

TRW

Paragraph/Requirement	Source	Capability	Verification
3.1.4.2.2.4 Thermal Redundant heaters provided to prevent propellant freezing. All heaters (excluding thruster catalyst bed heaters) controlled by redundant thermostats. Temperatures shall be monitored using TBD. All propulsion module thermal closeouts and external insulation installed at spacecraft level. Three catalyst bed heaters incorporated on each thruster to ensure achievement of thruster performance and life requirements OAS components that contain hydrazine maintained at all times > 40°F and < 85°C (185°F), except for thruster propellant valves where maximum allowable temperature resulting from thruster firing =116°C (240°F). Propellant tank temperature < 120°F. Thruster catalyst beds shall be > 177°C (350°F) prior to firing and during firing for normal operations.	SS3-055 SSTI OAS Specification	Complies	Analysis and inspection
3.1.4.2.2.4.1 Interface Temperatures Heaters sized to maintain required minimum temperatures with environments specified in D22888 at minimum spacecraft bus voltage as specified in paragraph 3.1.4.1.2.1 and a maximum duty cycle of 75%.	SS3-055 SSTI OAS Specification	Complies	Analysis and inspection
3.2.1.1.1 Thrust Level Thrust level of each thruster = 4.9 N (1.1 lbf) maximum at beginning-of-life (BOL) when thruster is fired continuously under normal operating conditions. Minimum end-of-life (EOL) thrust = 1.3 N (0.3 lbf).	SS3-055 SSTI OAS Specification	Complies. Thruster can operate from 4.9 to 0.9 N (1.1 to 0.20 lbf)	Analysis and test (hot fire thruster acceptance)
3.2.1.1.2 Thrust Duration Thrusters capable of operating at maximum continuous thrust (steady-state firing) for minimum of 1200 sec. No duty cycle limitations exist.	SS3-055 SSTI OAS Specification	Complies. Thruster qualified for maximum steady state firing of 187 minutes	Analysis and test (hot fire thruster acceptance)
3.2.1.1.3 Impulse Bit Impulse bit $\leq$ 0.23N-sec (0.05 lbf-sec) when using 30 msec electrical pulsewidth and firing duty cycle of 0.1 % or less.	SS3-055 SSTI OAS Specification	Complies. Thruster demonstrated impulse bit $\leq$ 0.09 N-sec (0.02 lbf-sec) for 30 msec pulse width and 0.1% duty cycle	Analysis and test (hot fire thruster acceptance)
3.2.1.1.4 Thruster Valve Response Opening time (electrical fire command to full open) $\leq$ 20 msec Closing time (electrical close command to full close) $\leq$ 15 msec	SS3-055 SSTI OAS Specification	Complies	Analysis and test

OAS Requirements vs Capabilities

Paragraph/Requirement	Source	Capability	Verification
3.2.1.1.5 Numbers of Thrusters OAS capable of operating any number or combination of thrusters on each of primary and secondary banks of four thrusters, except both thrusters on same DTM may not be operated simultaneously.	SS3-055 SSTI OAS Specification	Complies	Inspection
3.2.1.2 Total Impulse OAS provides minimum total impulse = 57,785 N-sec (13,000 lbf-sec)for steady-state delta-V and pulse-mode attitude control.	SS3-055 SSTI OAS Specification	Complies. Thruster qualified for $\geq$ 1,155,700 N-sec (260,000 lbf-sec)	Analysis and test
3.2.1.3 Propellant and Pressurant OAS designed to operate with monopropellant grade hydrazine per MIL-P-26536D and gaseous nitrogen pressurant per MIL-P-27401C.	SS3-055 SSTI OAS Specification	Complies	Analysis and inspection
3.2.1.4 Leakage Throughout its life, OAS liquid external leakage = 0 when OAS pressurized at ambient temperature between 6.9 and 27.6 bar (100 and 400 psia). Total OAS external leakage $\leq$ 10 scc/hr when pressurized internally with GHe at 8.6 +0,-1 Bar (125 +0,-15 psig). Leakage past any isolation valve or both seats of any thruster valve $\leq$ 5 scc/hr GN_2.	SS3-055 SSTI OAS Specification	Complies	Test (GHe internal leakage and external leakage)
3.2.1.5 Filtration OAS filter filtration rating $\leq$ 10 microns absolute.	SS3-055 SSTI OAS Specification	Complies. Filtration rating = 10 microns absolute	Test
3.2.1.6 Latching Isolation Valve Back pressure relief capability incorporated allowing upstream propellant flow if downstream pressure exceeds upstream pressure. Back pressure relief sized to preclude damage to downstream components due to excess pressure	SS3-055 SSTI OAS Specification	Complies. Maximum back pressure relief = 400 psid	Analysis and inspection
3.2.1.7 Operating Pressure Blowdown operating pressure range: 27.6 Bar (400 psia) at BOL [49°C (120°F) maximum] to 6.9 Bar (100 psia) at EOL [4°C (40° F) minimum].	SS3-055 SSTI OAS Specification	Complies	Analysis
3.2.2.1 Weight Total dry weight of final assembled OAS module $\leq$ TBD kg (TBD lbm) including all OAS components, lines, fittings, component mounting hardware, OAS electrical harnesses , and thermal hardware.	SS3-055 SSTI OAS Specification	Complies. Total OAS module dry weight = 15.3 kg (33.7 lbm)	Test

OAS Requirements vs Capabilities

Paragraph/Requirement	Source	Capability	Verification
3.2.2.2 Envelope Envelope shall not exceed dimensions specified in ICD-TBD and subsystem assembly drawings (TBD).	SS3-055 SSTI OAS Specification	Complies	Inspection
3.2.2.3.1 Proof and Burst Pressure Factors OAS designed to proof and burst factors defined in MIL-STD-1522A. OAS pressure-loaded components, except for tank and lines, factors: Minimum proof pressure = 1.5 x maximum operating pressure (MOP) Minimum burst pressure = 2.5 x MOP Propellant tank factors: Minimum proof pressure = 1.25 x MOP Minimum burst pressure = 1.5 x MOP Lines Minimum burst pressure = 4.0 x MOP.	SS3-055 SSTI OAS Specification	Complies Fill and Drain Valves Proof pressure = 1.5 x MOP Burst pressure = 3.5 x MOP Propellant Tank Proof pressure = 1.25 x MOP Burst pressure = 1.50 x MOP Latching Isolation Valve Proof pressure = 3.5 x MOP Burst pressure = 5.62 x MOP Pressure Transducer Proof pressure = 1.54 x MOP Burst pressure = 2.54 x MOP Thruster Valve Proof pressure = 3.94 x MOP Burst pressure = 6.56 x MOP	Analysis and test
3.2.2.3.2 Structural Components Safety Factors Structural components shall have a positive margin of safety at an ultimate load of 1.40 times the design load and a yield load of 1.25 times the design load.	SS3-055 SSTI OAS Specification	Complies	Analysis
3.2.2.4 Power Maximum power required for OAS operation defined in D-22885, Power Allocations Document. Individual component power requirements defined in respective equipment specifications. Specification power values shown in Table 3-7.	SS3-055 SSTI OAS Specification	Complies. Maximum required operational OAS power < value specified in D-22885.	Analysis
3.2.3.1 Reliability Reliability requirements defined in D-22876, SSTI Reliability Implementation Plan (in house equipment) or PAR 700-417, SSTI Subcontractor Performance Assurance Requirements (subcontractor equipment).	SS3-055 SSTI OAS Specification	Complies	Analysis and inspection

OAS Requirements vs Capabilities

Paragraph/Requirement	Source	Capability	Verification
3.2.3.2 Life Life defined as period of time/cycles during which end item will not wearout or degrade such that it cannot meet its specified requirements. All OAS components shall support 5 years of orbital operation subsequent to 1 year of storage. Components with a demonstrated cycle life > 2:1 margin shall be designated as "limited life" items and require accumulated time/cycle tracking during fabrication, test, storage, and mission operation.	SS3-055 SSTI OAS Specification	Complies. No life limited OAS components used.	Analysis
3.2.3.3 Reliability Allocation OAS reliability allocated in D-22876 ≥ TBD at the end of 5 years for the spacecraft.	SS3-055 SSTI OAS Specification	Complies. OAS reliability ≥ TBD at end of 5 years	Analysis
3.2.3.4 Single Point Failure Avoidance OAS design shall minimize single point failures. Hardware with FMEA severity categories 1, 1R, 1S, or 2 (i.e., mission or safety critical and nonredundant) defined in D-22876 shall be identified.	SS3-055 SSTI OAS Specification	Complies. OAS single fault tolerant with primary and redundant set of thrusters. During launch, 3 inhibits to propellant leakage provided: dual seat thruster valves and latching isolation valve upstream of thrusters. On orbit, 2 inhibits provided: dual seat thruster valves	Analysis
3.2.3.5 Storage Life OAS ground storage life = 1 year. During storage or other non-flight inoperative periods, OAS pressurized with dry GHe per MIL-P-27407A or dry GN_2 per MIL-P-27401C to 1.7 ± 1.4 Bar (25 ± 20 psig).	SS3-055 SSTI OAS Specification	Complies. No life limited OAS components used.	Analysis
3.2.3.6 Operational Life OAS operational life = 5years.	SS3-055 SSTI OAS Specification	Complies. No life limited OAS components used.	Analysis
3.2.4 Environmental Conditions OAS designed to withstand environments specified in EV-099 during spacecraft level testing, ground operations, and launch.	SS3-055 SSTI OAS Specification	Complies. All components except propellant tank qualified. Propellant tank currently undergoing qualification tests.	Analysis and test (qualification and acceptance)

OAS Requirements vs Capabilities

Paragraph/Requirement	Source	Capability	Verification
3.2.5 Maintainability OAS designed to permit removal and replacement of any equipment on spacecraft while minimizing disturbance to associated or adjacent equipment.	SS3-055 SSTI OAS Specification	Complies.	Analysis and inspection
3.2.6 Transportability OAS transported either as part of the spacecraft or by its attachment structure subject to the requirements specified in 3.1.4.2.2.2.	SS3-055 SSTI OAS Specification	Complies	Analysis and inspection
3.2.7 Accessibility Mechanical and electrical interfaces accessible for testing and servicing without need for reconfiguration.	SS3-055 SSTI OAS Specification	Complies	Analysis and inspection
3.3.1 Parts, Materials and Processes Parts, materials and processes selected in accordance with D-22876 and subcontractor PAR 700-417.	SS3-055 SSTI OAS Specification	Complies	Inspection
3.3.2 Electromagnetic Compatibility Propulsion subsystem designed to operate through electromagnetic environment produced by operation of spacecraft subsystems and SSTI instruments without critical function degradation. OAS designed to the electromagnetic compatibility requirements of SR1-0125.	SS3-055 SSTI OAS Specification	Complies	Analysis
3.3.3 Electromagnetic Interference (EMI) Propulsion subsystem shall not generate, conduct, or radiate any electromagnetic signal that damages, degrades, or otherwise interferes with OAS, another subsystem, or instrument.	SS3-055 SSTI OAS Specification	Complies	Analysis
3.3.4 Marking Applicable OAS components marked in accordance with requirements of PR12-6 and subcontractor PAR 700-417. Markings shall include: • Item nomenclature • TRW P/N and S/N • Manufacturer's P/N and revision letter • Date of manufacture • Actual weight in pounds • Government contract number	SS3-055 SSTI OAS Specification	Complies	Inspection

OAS Requirements vs Capabilities

Paragraph/Requirement	Source	Capability	Verification
3.3.5 Workmanship OAS and its components constructed, finished, and assembled in accordance with requirements depicted in applicable drawings, specifications and standards, and as further delineated by quality operating instructions, process specifications and workmanship manual (WSM).	SS3-055 SSTI OAS Specification	Complies	Inspection
3.3.6 Cleanliness OAS components and subassemblies conform to cleanliness requirements specified in specifications and drawings. Lines and fittings cleaned to meet requirements of PR2-2-12, (Level S), prior to assembly. Propellant tank cleaned in accordance with PR2-2-3. OAS assembled in clean room environment meeting requirements of FED-STD 209C, Class 10,000.	SS3-055 SSTI OAS Specification	Complies	Inspection
3.3.7 Safety OAS designed to preclude or limit hazards to personnel and equipment, and prevent wetted components from exceeding 185°F. OAS designed to be two fault tolerant against inadvertent propellant flow. OAS design to comply with D-22876.	SS3-055 SSTI OAS Specification	Complies. During launch, 3 inhibits to propellant leakage provided: dual seat thruster valves and latching isolation valve upstream of thrusters. On orbit, 2 inhibits provided: dual seat thruster valves	Analysis and inspection
3.3.8 Interchangeability Each major equipment item of OAS to be directly interchangeable in form, fit and function with other equipment items of same part number. Performance characteristics and dimensions of like units to be sufficiently uniform to permit equipment interchange while minimizing adjustment and recalibration.	SS3-055 SSTI OAS Specification	Complies	Inspection

SSTI

OAS Interface

- Telemetry
  - Temperature; lines (4), tank (2) , thrusters (8)
  - Pressure; (1)
  - Status; thrusters (8), isolation valve position (2), transducer (1), heaters (3 cat bed and 2 system)
- Commands
  - Heaters (3 cat bed, 2 system), tank (2) system (2)
  - Transducer power (1)
- Electrical
  - Connector Bracket located on BPM for thermal hardware
  - DTM dedicated connectors on DTM plate
  - Transducer and ISO valves have separate connectors
- Structural
  - Tank mounted to central cylinder
  - Thrusters mounted to outer cylinder
  - PDM and FDM located on horizontal platform (same as batteries)

OAS Weight Estimate

Item	Quantity per OAS	Specification Unit Weight (kg)	Specification Unit Weight (lb)	Total Weight (kg)	Total Weight (lb)
Propellant Tank	1	6.8	15.0	6.8	15.0
Fill and Drain Valve	2	0.1	0.2	0.2	0 .4
Pressure Transducer	1	0.5	1.1	0.5	1.1
Filter	1	0.3	0.7	0.3	0.7
Dual Thruster Module	4	1.3	2.8	5.2	11.2
Isolation Valve	2	0.3	0.6	0.5	1.1
Interconnecting Line Assembly	set	0.6	1.2	1.0	2.2
Mounting Hardware	set	0.9	2.0	0.9	2.0
OAS Insulation	set	0.5	1.0	0.5	1.1
Heaters	set			0.3	0.7
Total				**16.2**	**35.5**

OAS Power

COMPONENT	UNIT POWER (WATTS) @24vdc	QTY.	TOTAL UNITS POWER (WATTS) @24vdc	DUTY CYCLE (%)	ORBIT AVERAGE POWER (WATTS)	BASIS
Propellant Tank Heaters	1.3, 2.25	4 each	14.21	70	9.95	3.64 W @ Top,6.31W @ skirt
PDM Heaters	2.08	2	4.16	70	2.91	4 GEB supports
FDM Heaters	2.23	1	2.23	70	1.56	6 GEB supports
Propellant Lines Heaters	Various	TBD	7.52	70	5.26	128" external lines @ 0.30W/ft, 165" internal lines @ 0.15 W/ft
Catalyst Bed Heaters*	1.68	8	13.44	100	4.5	Based on 24 Vdc except orbit average power at 34vdc
Thruster Valve Heaters	3.14	8	25.1	70	17.6	3.14 Watts per heater, primary circuit heats both primary and redundant thrusters
Thruster Valves**	19.86	8	158.9	0	0	Calculated using 24 Vdc and resistance of 29.03 ohms
Isolation Valves**	13.67	2	27.33	0	0	Calculated using 24 Vdc and valve coil resistance of 80 ohms
Pressure Transducer	0.5	1	0.5	100	0.5	Plus resistor in harness (TBD ohms)
OAS TOTALS	N/A	N/A	253.4	N/A	42.3	

* Values quoted are total per thruster except for orbit average, one heater per redundant thruster always 'on'

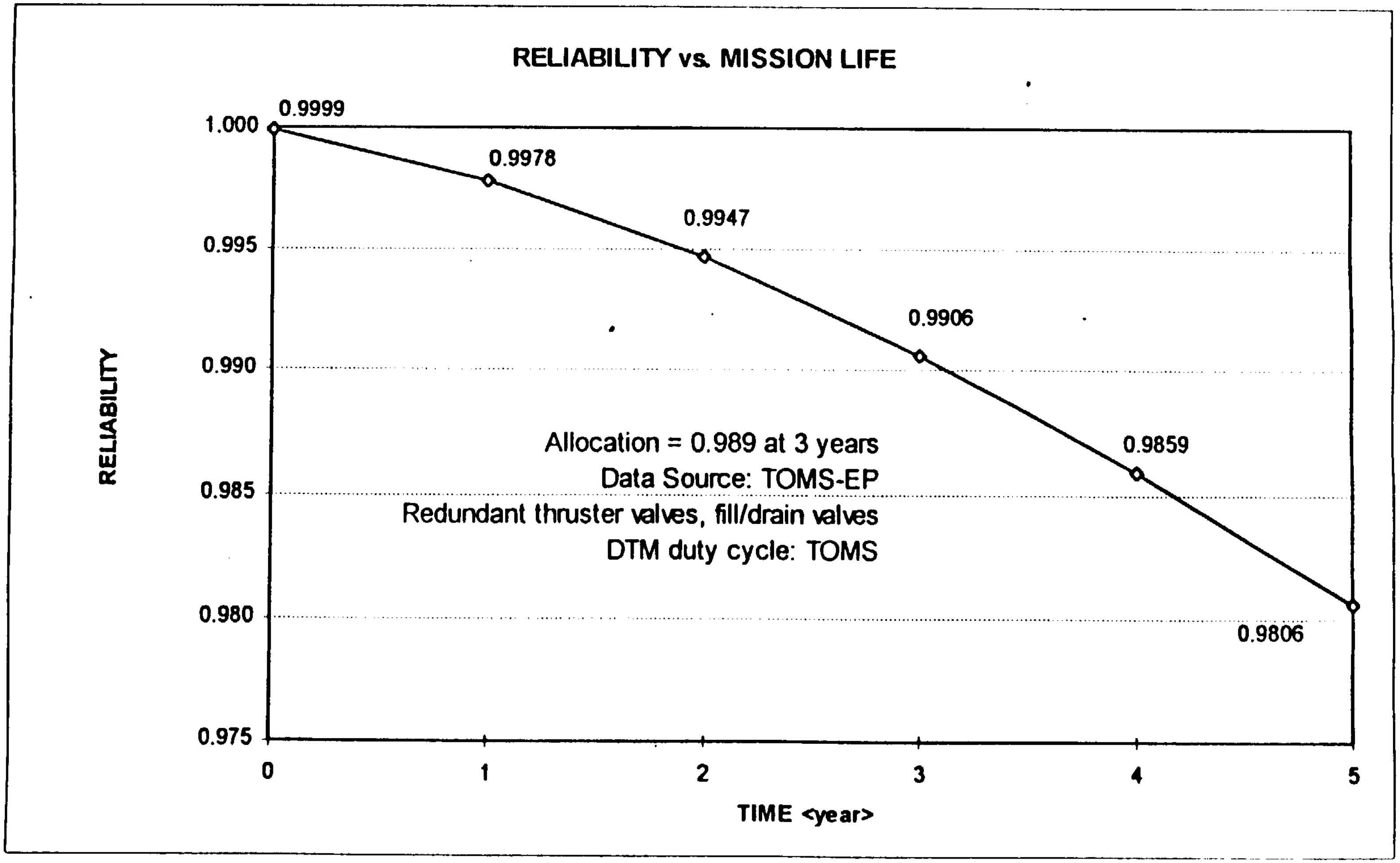
** Valves commanded as necessary, for orbit average calculation use duty cycle of 0%

Note: All heaters were sized using coldest interface temperatures (eclipse exit and coldest orbit).

Note: All heaters were sized at 24 Vdc unless otherwise stated.

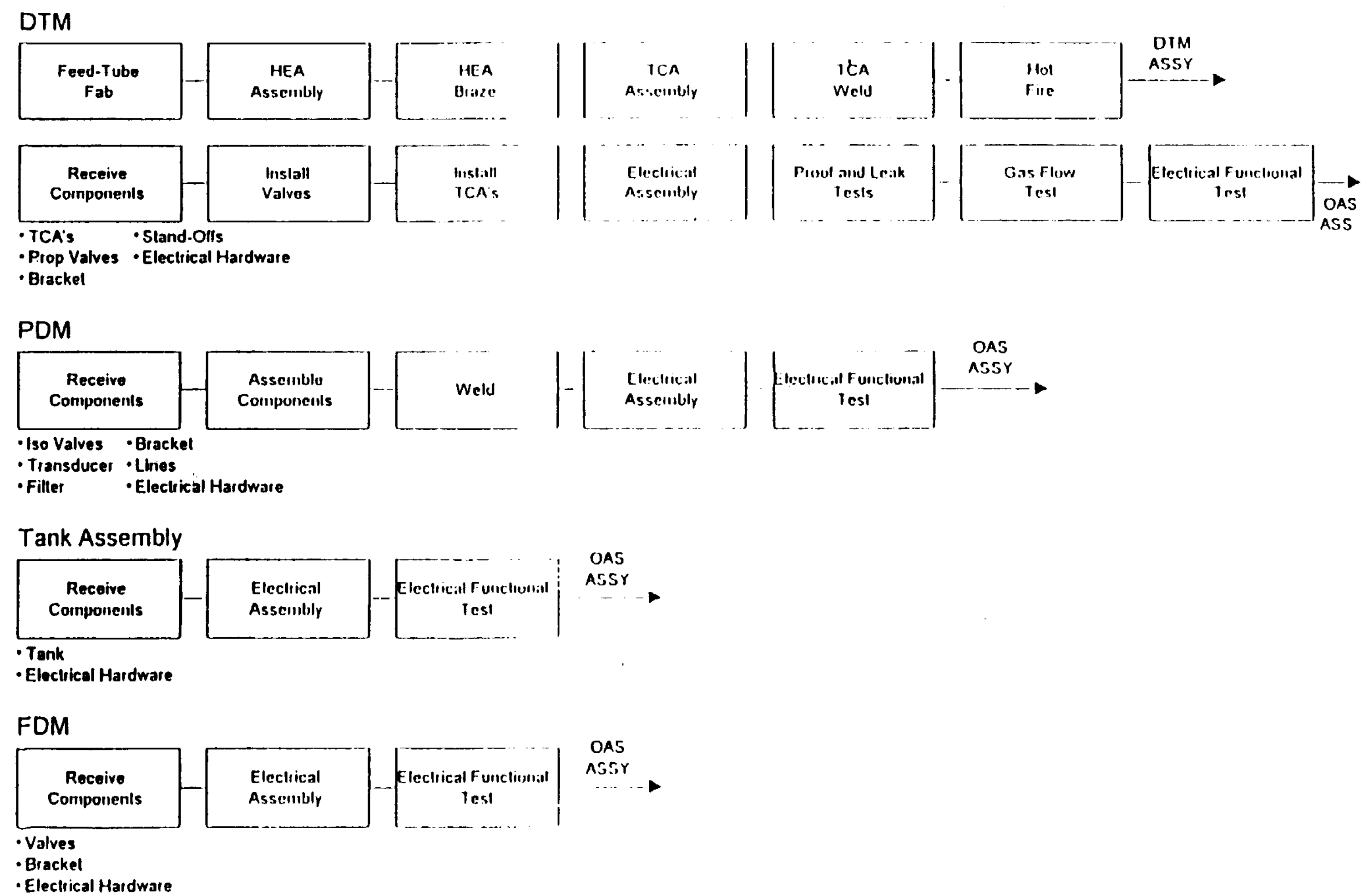
OAS Reliability

- **Reliability prediction exceeds allocation at 3 years**

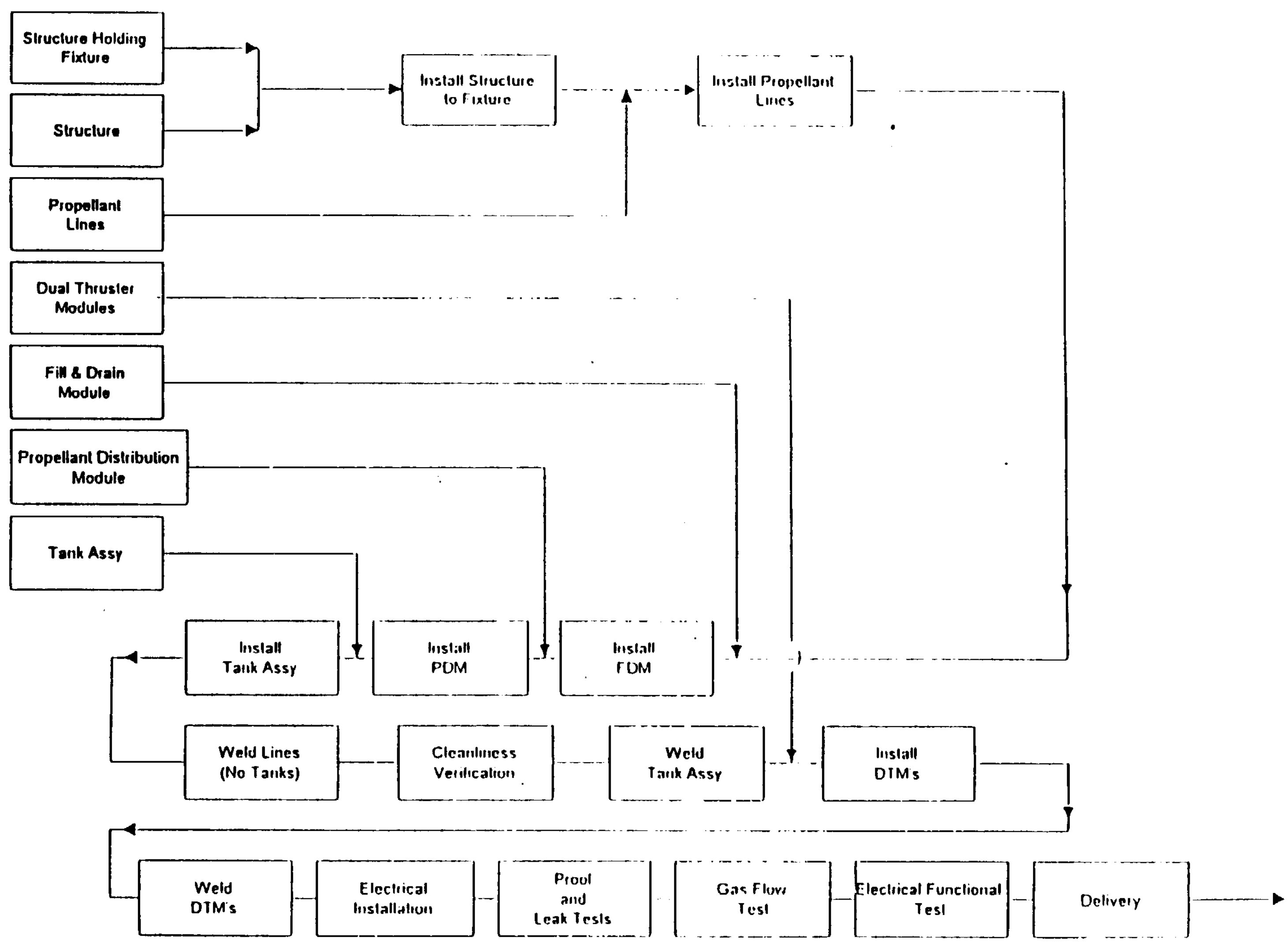


OAS AI&T Flow

Modules Assembly



OAS AI&T Flow



Structure Holding Fixture
Structure
Propellant Lines
Dual Thruster Modules
Fill & Drain Module
Propellant Distribution Module
Tank Assy
Install Structure to Fixture
Install Propellant Lines
Install Tank Assy
Install PDM
Install FDM
Weld Lines (No Tanks)
Cleanliness Verification
Weld Tank Assy
Install DTM's
Weld DTM's
Electrical Installation
Proof and Leak Tests
Gas Flow Test
Electrical Functional Test
Delivery

OAS Testing

- SUBSYSTEM TESTS
  - Head-end Assy & Thruster Chamber Assy
    - Feed tube water flow test
    - Head-end assy water flow test
    - Thrust chamber assy hot-fire acceptance test
  - Dual Thruster Module
    - Proof & External Leak
    - Internal Leak
    - Gas Flow Impedence
    - Electrical Functional
  - On-orbit Adjust System
    - Cleanliness Verification - less tanks
    - Proof, Internal/External Leak, Gas Flow
    - Electrical Functional

OAS Risk and Risk Mitigation

Identified Risk	Risk Mitigation
Propellant tank qualification and manufacture	• Same size tank with .010 in. liner already passed qualification demonstration • TRW/SCI has agreed on expedited schedule for early recognition of potential problems • Four critical assemblies (liners) already manufactured; SSTI only needs 2
Range safety acceptance of propellant tank	• Continuous coordination with WTR safety. Invited to both CDA reviews. New mandates published regarding acceptance of O/W propellant tanks. • Special review anticipated at WTR
Cost	• ICMT of filter, transducer and F/D valves mitigate subcontract risk. Common buy with DSP for iso valve. Early completion of NRE assures identification of problems.
Schedule	• Component procurements structured to minimize schedule risk. All modules completed prior to structure delivery • Integrated schedule and cost management tools, data reviewed weekly
System proof pressure demonstration	• Similarity analysis and inspection to show acceptable margins • System will be proof tested to 1.5 MEOP (upstream of latching isolation valves)

SSTI

OAS Open Items

TRW

- Propellant tank qualification
- Detail design of system brackets and installation
- Drawings scheduled to be complete by mid February
- Propellant loading cart
- Range safety compliance
  - Propellant tank
  - System proof pressure demonstration
  - Launch configuration
- Fluids analysis and initialization transients

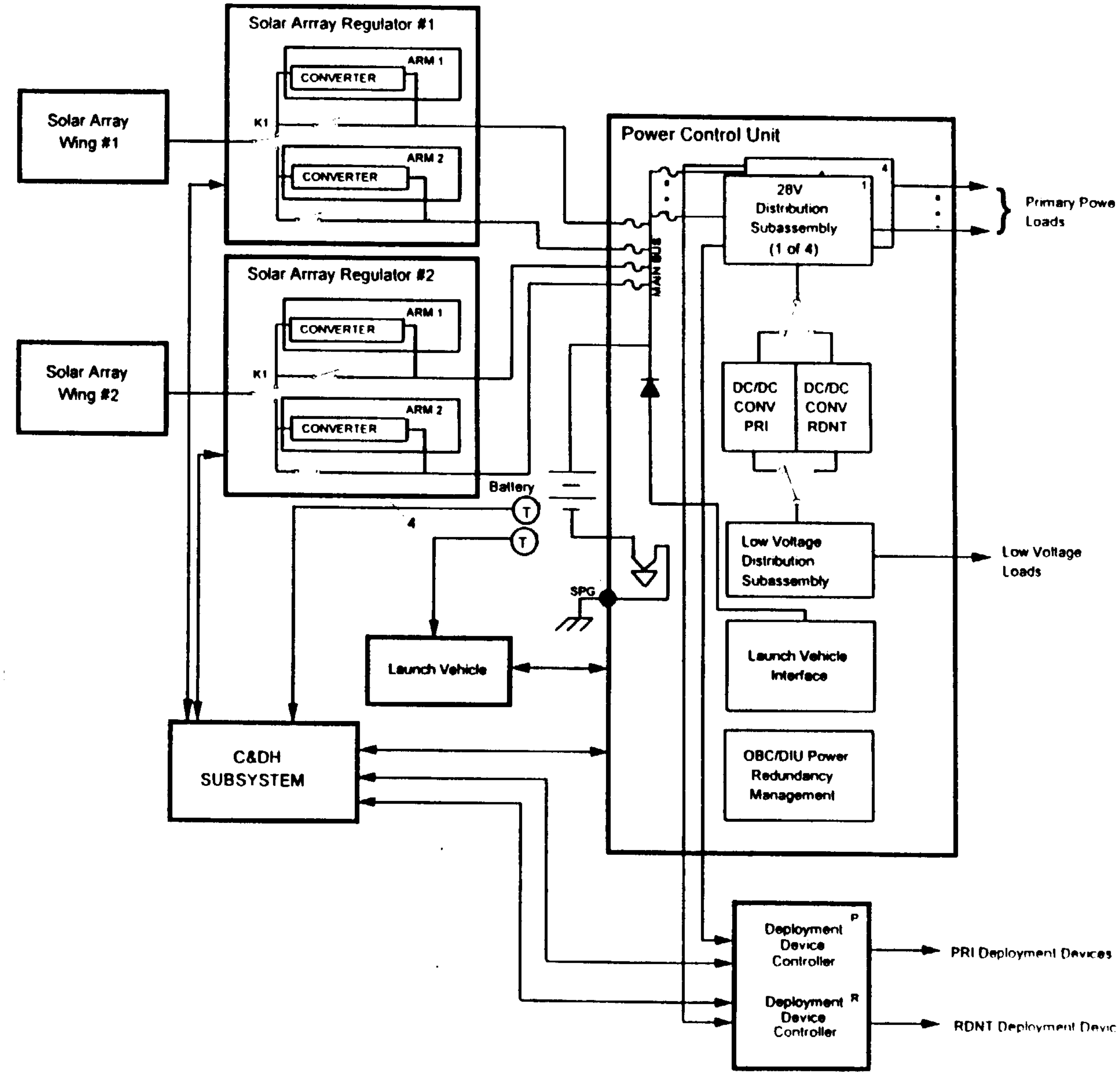
SPACECRAFT BUS
Electrical Power & Distribution

B. Starritt

Subsystem Overview

SSTI

EPDS Block Diagram



Functional Summary

- Solar Array
  - Primary source of electrical power (740W EOL/5 years)
  - Silicon solar cells, CMX coverglass, Graphite/Al honeycomb substrate
- Battery
  - Provides electrical power during eclipses (5700/year)
  - 23 AH capacity, 24 cells in 12 2-cell common pressure vessels
- Solar Array Regulator
  - Adjusts solar array output to control battery charging
  - Buck-type converter; duty cycle determined by external command
- Power Control Unit
  - Provides control and distribution for all electrical loads
  - Provides secondary power to certain spacecraft units

SSTI

Functional Summary

TRW

- Deployment Device Controller
  - Contains control channels to operate up to eight solar array release devices
- Software
  - Controls battery charging
  - Maintains battery SOC data (AH integration)
  - Detects anomalous subsystem behavior

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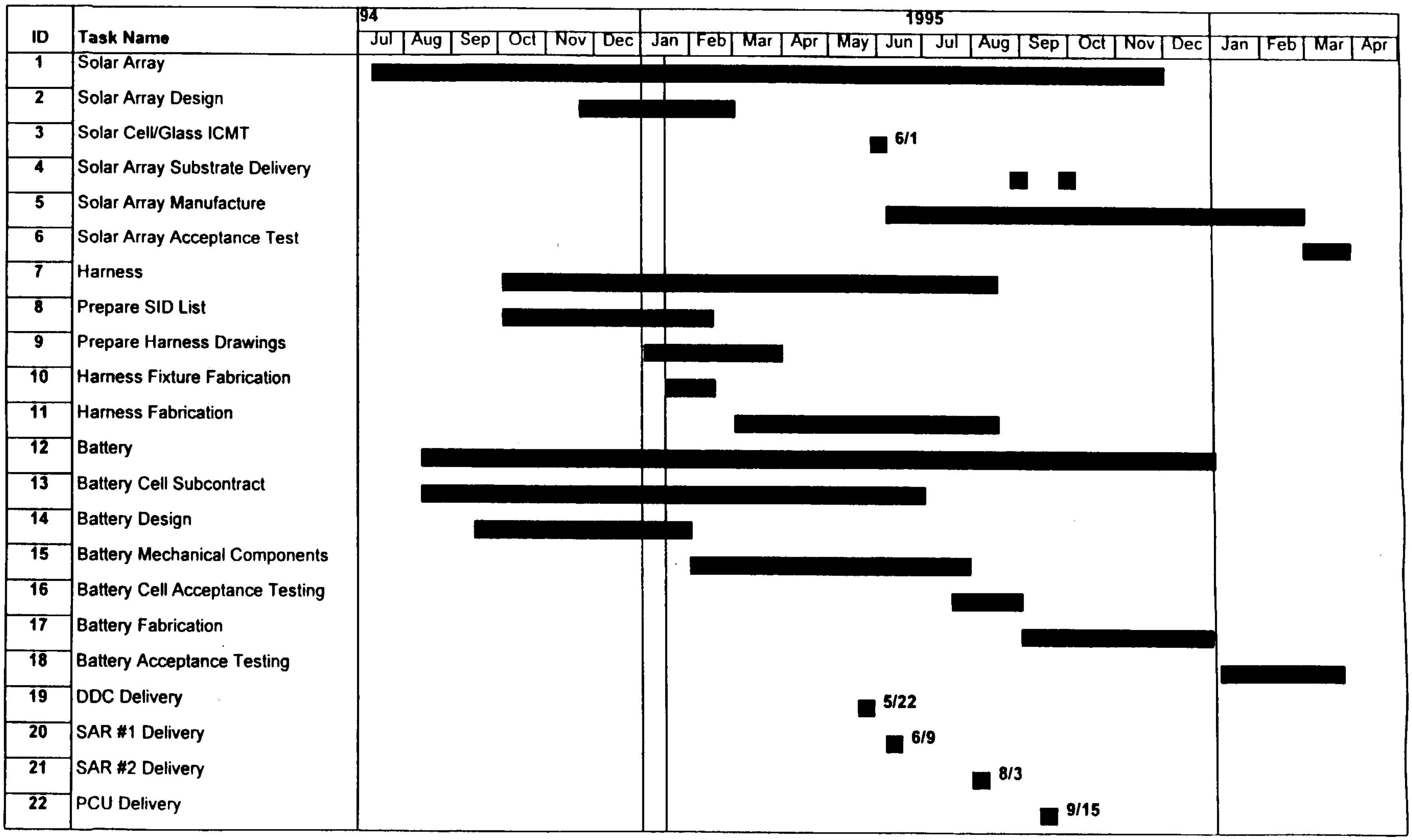
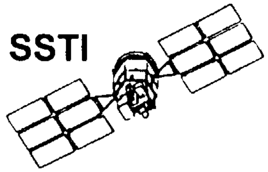
EPDS Schedule Summary

TRW



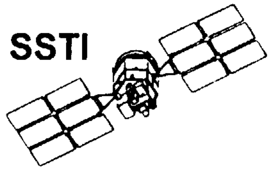


Requirements vs. Capabilities

Requirement	Capability
• Provide electrical power to spacecraft and payload users	• Battery will supply 325 W in eclipse to 29% DOD (31.5% w/2 cells shorted) 740 W array (Year 5) can support 400W in sunlight and recharge battery
• Maintain bus voltage between 38.6 and 24.0 V nominal, 23.0 w/c minimum	• EOL battery with 24 cells will not exceed 1.61V/cell on charge, 22-cell battery will not be < 1.09V/cell on discharge
• Provide +5, ±15V for secondary power users	• Redundant PCU converters deliver 5.45V±2% @ 4.25A, +&-14.9V±4% @ 1.23A

Requirements vs. Capabilities

Requirement	Capability
• Provide fault isolation for all loads	• Primary power loads are all fused Converter loads are protected by hardware-based automatic disconnection and fuses
• Provide power switching and controls	• PCU provides the following load controls: – 41 switched outputs for primary power – 12 converter soft switch outputs – 14 switched outputs for secondary power – 48 pulse commands



Requirements vs. Capabilities

Requirement	Capability
• Provide controls for solar array release devices	• DDC has redundant controls for eight non-explosive release devices
• Provide launch vehicle interfaces	• Diode-isolated input (7.4A max) to primary power bus for on-stand satellite operation and battery charging Conditioning circuits for separation breakwires

Requirements vs. Capabilities

Requirement	Capability
• Provide for controlled battery recharging	• Software controls battery charge current as a function of state of charge. AH integration is primary, voltage-limited charging is used for contingencies.
• Provide peak power tracking of solar array output	• Software computes peak power voltage and sets SAR duty cycles to operate there for max-rate charging Spacecraft solar array I/V data can be collected on request by the ground to update the peak power tracker.

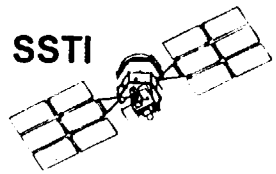
SSTI

Hardware Status

TRW

- Solar Array
  - Determined panel size and string layouts
  - Selected DSP solar cells/glass
    - Cells & glass in-house; need only ICMT before June
  - Beginning detailed layouts (wiring, etc.)
- Battery
  - Final MCD review last week
  - Positive plates completed, negative plates scheduled to be complete this week
  - Pressure vessels in-house
  - Cell-to-cell isolation process improvements:
    - Teflon coating process for weld ring developed
    - Tests to ensure that welding does not debond Teflon are upcoming
    - Similar cells without Teflon have been subjected to ≈12,500 cycles without shorting

SSTI



Hardware Status

TRW

- Solar Array Regulators
  - Requirements finalized
  - Design and drafting efforts complete
  - Kitting parts as they arrive to begin fab late March
- Power Control Unit
  - PCU requirements finalized; design effort nearly complete
  - Drafting under way (complete early March)
- Deployment Device Controller
  - Requirements finalized
  - Design and drafting efforts complete
  - Kitting parts as they arrive to begin fab late March
- Harness
  - Completed interconnect diagram and assigned refernce designators
  - Beginning SID list; have received pinouts for many but not all units. Pinouts are urgently needed.

Verification Plans

- Electronic units (PCU, SAR, DDC) will be tested by vendor
  - Units will be vibration tested and thermal cycled at ambient pressure
  - PCU will be tested to protoqual levels, SAR and DDC to acceptance levels
- Battery will be tested by vendor and by TRW
  - Cells receive basic acceptance charge/discharge cycling at vendor
  - Cells will be acceptance cycled at TRW before assembly into battery
  - Battery cell modules will be vibration tested; one at protoqual levels, five at acceptance levels
  - Battery assembly will be cycled before delivery to I&T
  - Batteries are not temperature-cycled; acceptance cycling is performed at a variety of temperatures

Verification Plans

- Solar array will be tested by TRW
  - Assembled wings will be thermal cycled at ambient pressure (deployed) and acoustically tested (stowed)
- Harnesses will be vacuum-baked and Hipot tested by vendor
- Software verification has several levels
  - Low-level (function-level) testing will be performed during development
  - High-level (behavioral) will be performed at the spacecraft level and on development systems
- Subsystem verification is essentially the high-level software verification

SSTI

TRW

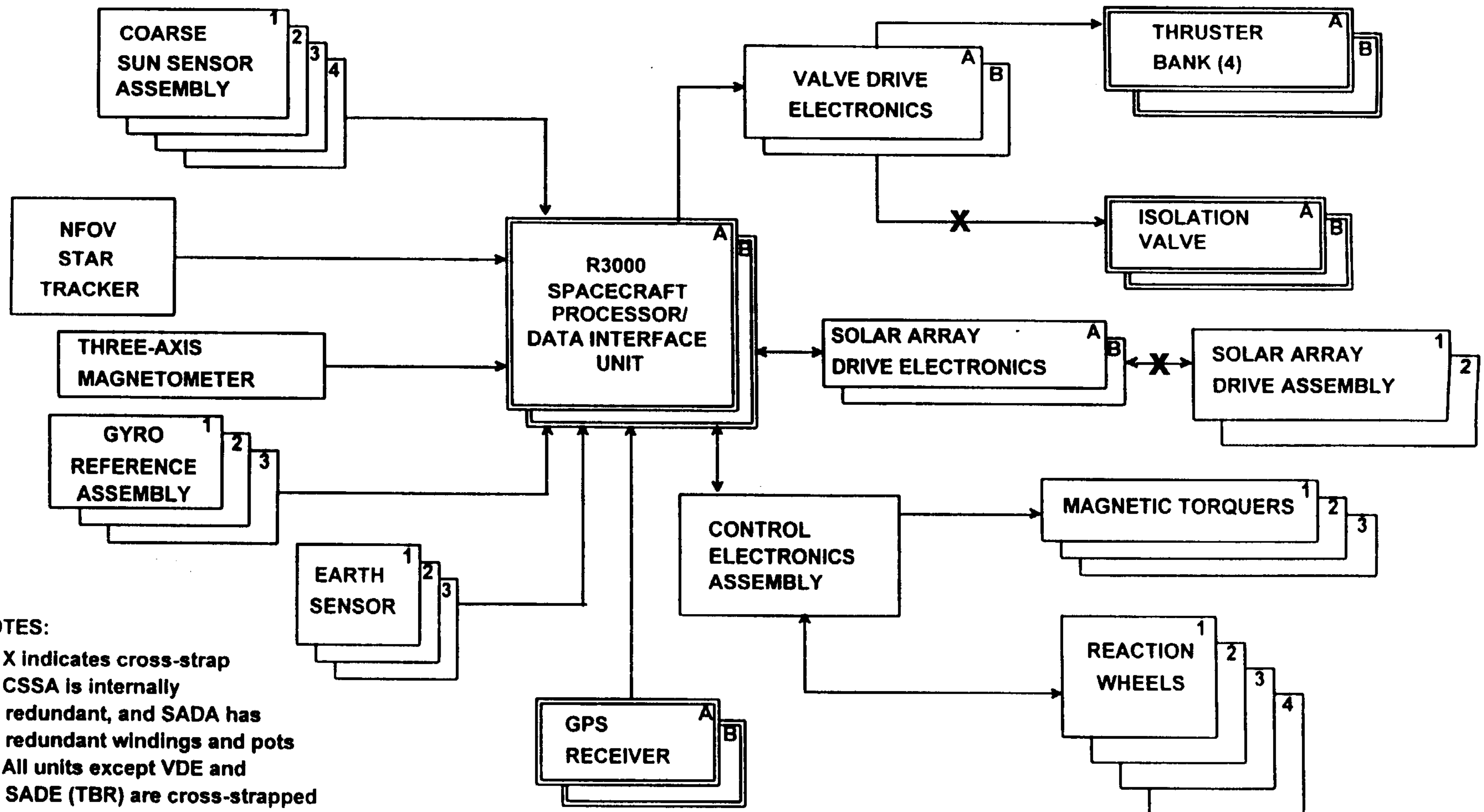
SPACECRAFT BUS
GN&C

P. Parry

GN&C Description

- Functions
  - Determine s/c position
  - Determine s/c attitude
  - Control attitude relative to nadir and sun
  - Provide attitude stabilization
  - Point solar arrays at sun
- Hardware Employed
  - TRW Coarse Sun Sensor Assemblies
  - HDOS HD-1003 Narrow Field of View Star Tracker
  - Ideas/Nanotesla Three-Axis Magnetometer
  - Kearfott TARA Gyro Reference Assemblies
  - Barnes 13-470 Earth Horizon Sensor Assemblies
  - Loral Tensor GPS Receiver
  - ITHACO Type A Reaction Wheels
  - ITHACO TR10CFR Torqrods
  - Schaeffer Magnetics Type 2 Rotary Incremental Actuators
  - TRW/Jackson & Tull Valve Drive Electronics

GN&C Block Diagram



NOTES:

(1) X indicates cross-strap

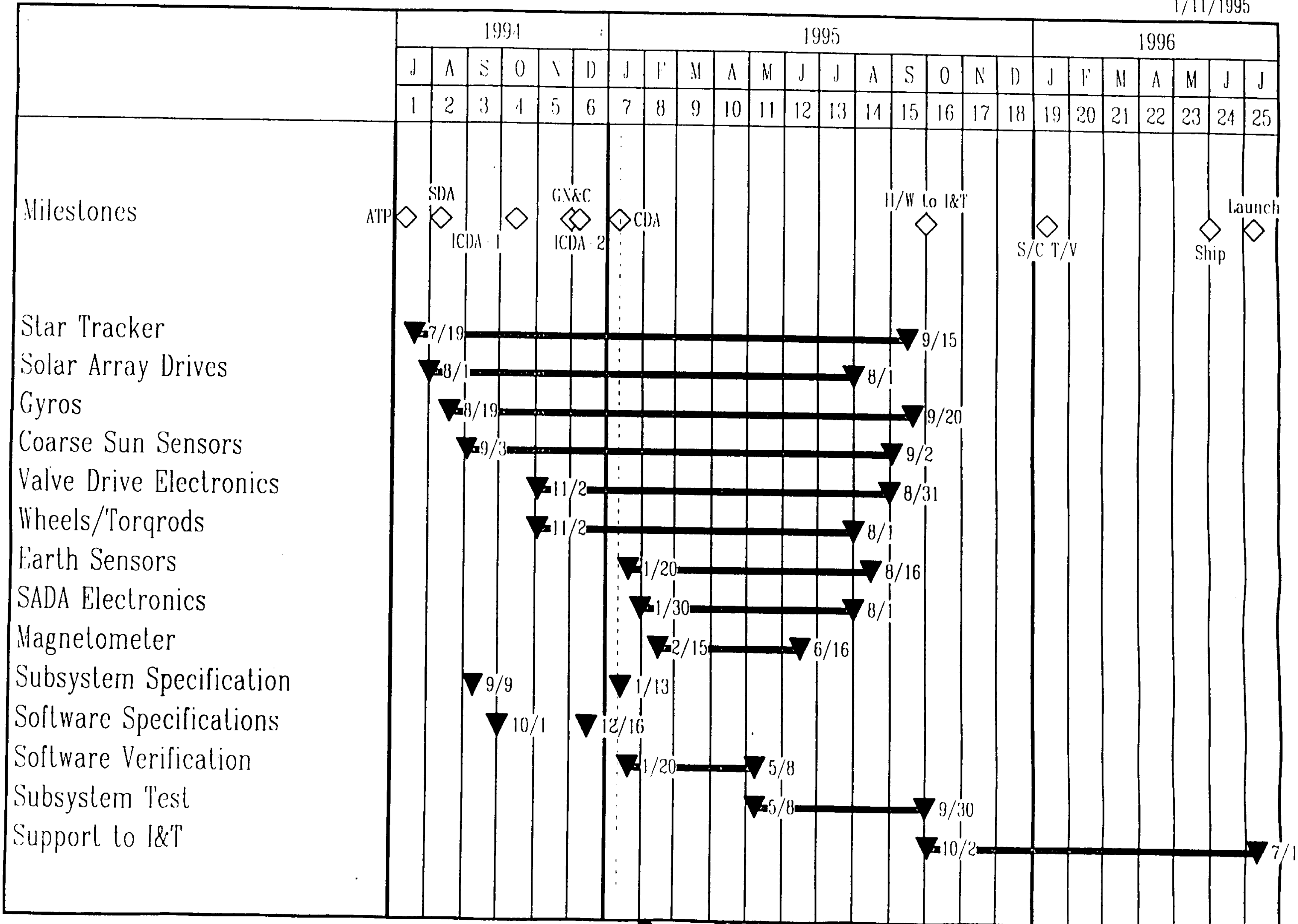
(2) CSSA is internally redundant, and SADA has redundant windings and pots

(3) All units except VDE and SADE (TBR) are cross-strapped to Spacecraft Processors

(4) Doulble-lined boxes indicate units provided by other subsystems

SSTI GN&C SUBS[illegible]EM SCHEDULE

1/11/1995



SSTI

GN&C Requirements vs. Capabilities

TRW

Description	Requirement (3-sigma)	Capability
S/C Position Knowledge	150 meters	<150 meters
Attitude Knowledge	10 arc-sec roll	6 arc-sec roll
(Nadir Operations)	30 arc-sec pitch	22 arc-sec pitch
	50 arc-sec yaw	22 arc-sec yaw
(Inertial Operations)	0.25 deg each axis	< 0.2 deg each axis
Attitude Control	0.04 deg roll, pitch	0.02 deg each axis
(Nadir Operations)	0.5 deg yaw	
(Inertial Operations)	0.4 deg each axis	< 0.2 deg each axis
Drift Rate Stability	10 arc-sec in one sec	5 arc-sec in one sec
(Nadir Operations)		
Offset Pointing From	22 deg roll, 50 deg pitch,	Comply
Nadir	3.8 deg yaw	
Point Solar Arrays at Sun	within 5 deg in pitch	within 2 deg in pitch

Table 4-1. Requirements Verification Matrix

Paragraph	Title	Method				Traceability/ Comments
		T	A	I	D	
3.1	**SUBSYSTEM DEFINITION**					N/A - Title
3.1.1	General Description		X			
3.1.2	Subsystem Configuration					N/A - Overview
3.1.3	Interface Definition	X	X			
3.1.3.1	Mass Properties		X			
3.1.3.2	Structural Flexibilities		X			
3.1.3.3	Thruster Characteristics					N/A - Intro
3.1.3.3.1	Locations and Directions	X	X			
3.1.3.3.2	Thrust Level	X				
3.1.3.3.3	Impulse Bit	X				
3.1.3.3.4	Valve Response	X				
3.1.3.3.5	Plume Impingement		X			
3.1.3.4	Angular Momentum Disturbance		X			
3.1.3.5	Thermal Requirements	X	X			
3.1.3.6	Primary and Secondary Power	X				
3.1.3.7	Signal Interfaces	X	X			
3.1.3.8	Commands	X				
3.1.3.9	Telemetry	X			X	
3.1.3.10	Flight Software Processing	X				
3.1.3.11	Ground Support		X		X	
3.2	**CHARACTERISTICS**					N/A - Title
3.2.1	Performance Characteristics					N/A - Title
3.2.1.1	Functional Requirements					N/A - Intro
3.2.1.1a	Stabilization after separation		X			
3.2.1.1b	Sun acquisition		X			
3.2.1.1c	Nadir pointing		X			
3.2.1.1d	Maneuver to burn attitude		X			
3.2.1.1e	Attitude control during burn		X			
3.2.1.1f	Attitude determination		X			
3.2.1.1g	Telemetry	X				
3.2.1.1h	Actuator activation by ground cmd	X				
3.2.1.1j	Fail safe using thrusters		X			
3.2.1.2	Operating Modes and Conditions	X	X			
3.2.1.2.3	Maneuver Mode	X	X			
3.2.1.2.4	Normal Mode	X	X			
3.2.1.2.6	Safe Haven Mode	X	X			
3.2.1.2.7	Earth Acquisition	X	X			
3.2.1.2.8	Fail-Safe Response	X	X			
3.2.1.3	Attitude Determination Performance					N/A - Title
	Onboard accuracy wrt LVLH		X			

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Table 4- 1. Requirements Verification Matrix (cont'd)

Paragraph	Title	Method				Traceability/ Comments
		T	A	I	D	
	Attitude update error		X			
	Attitude propagation error		X			
3.2.1.4	Normal Mode Performance					N/A - Title
	Mode activation	X				
	Attitude pointing error		X			
	Short-term attitude stability		X			
	Momentum storage capability		X			
	Momentum unloading		X			
3.2.1.5	Maneuver Mode Performance					N/A - Title
	Mode activation	X				
	Tip-off rate from separation		X			
	Activation delay		X			
	Attitude pointing error		X			
	Maneuver capability		X			
	Maneuver settling time		X			
3.2.1.7	Safe Haven Mode Performance					N/A - Title
	Mode activation	X				
	Initial spacecraft momentum		X			
	Initial attitude		X			
	Final attitude		X			
	Sun acquisition time		X			
	Sun-pointing error		X			
	Roll rate bias		X			
3.2.2	Physical Characteristics					N/A - Title
3.2.2.1	Component Requirements					N/A - Title
3.2.2.1.1	Gyro Reference Assembly	X	X			
3.2.2.1.2	Earth Sensor Assembly	X	X			
3.2.2.1.3	Reaction Wheel Assembly	X	X			
3.2.2.1.4	Magnetic Torquer Assembly	X	X			
3.2.2.1.5	Three-Axis Magnetometer	X	X			
3.2.2.1.6	Control Electronics Assembly	X	X			
3.2.2.1.7	Valve Drive Electronics Assembly	X	X			
3.2.2.1.8	Coarse Sun Sensor Assembly	X	X			
3.2.2.1.9	Narrow Field of View Star Tracker Assembly	X	X			
3.2.2.1.10	Solar Array Drive Electronics	X	X			
3.2.2.1.11	Solar Array Drive Assembly	X	X			
3.2.2.1.12	GNCS Flight Software	X				
3.2.2.1.12a	Attitude determination	X				

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Table 4- 1. Requirements Verification Matrix (cont'd)

Paragraph	Title	Method				Traceability/ Comments
3.2.2.1.12b	Gyro rate bias calibration	X				
3.2.2.1.12c	Control error determination	X				
3.2.2.1.12d	Control laws	X				
3.2.2.1.12e	Wheel momentum unloading	X				
3.2.2.1.12f	Attitude maneuvers	X				
3.2.2.1.12g	Failure detection	X				
3.2.2.1.12h	Sun acquisition	X				
3.2.2.1.12i	Earth acquisition	X				
3.2.2.1.12j	Solar array pointing	X				
3.2.2.2	Weight and Size	X				
3.2.2.3	Electrical Power	X	X			
3.2.2.4	Alignment Requirements					N/A - Title
3.2.2.4.1	Spacecraft Control Axes	X		X		
3.2.2.4.2	GRA Alignment	X		X		
3.2.2.4.3	Earth Sensor Alignment	X		X		
3.2.2.4.4	Coarse Sun Sensor Alignment	X		X		
3.2.2.4.5	Narrow Field of View Star Tracker Alignment	X		X		
3.2.2.4.6	Magnetometer Alignment	X		X		
3.2.2.4.7	Magnetic Torquer Alignment	X		X		
3.2.2.4.8	Solar Array Drive Assembly Alignment	X		X		
3.2.2.4.9	Reaction Wheel Alignment	X		X		
3.2.3	Reliability		X	X		
3.2.3.1	Storage and Operating Life		X			
3.2.3.2	Reliability Numberss		X			
3.2.3.3	Critical Items		X	X		
3.2.3.4	Single-Point Failure Avoidance		X			
3.2.4	Environmental Conditions	X	X			
3.3	**DESIGN AND CONSTRUCTION**					N/A - Intro
3.3.1	Parts, Material and Processes			X		
3.3.1.1	Parts Derating		X			
3.3.1.2	Parts Screening	X		X		
3.3.1.3	Finish		X			
3.3.1.4	Space Stability		X			
3.3.2	Electromagnetic Compatibility	X	X			
3.3.3	Workmanship			X		
3.3.4	Interchangeability			X		
3.3.5	Safety		X	X		
3.3.6	Nameplates and Marking			X		
3.3.7	Cleanliness			X		
3.4	**DOCUMENTATION**			x		

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GN&C Design Status

TRW

- Second Revision of Software Requirements Complete
  - Formal release next week
- Normal Mode Design Complete
  - Linear analysis with bending modes performed
  - Star tracker-based attitude update design complete
  - Simulations show acceptable performance in both nadir and inertial pointing operations
- Simulation Fully Functional for Normal Mode Pointing Operations
  - Full environmental disturbance torque modeling (solar, gravity-gradient, aerodynamic, magnetic)
  - Nine NASTRAN bending modes included
  - SADA torques
  - Wheel, star tracker, and Torqrod models

GN&C Design Status (Continued)

- Safe Haven Mode Trade Study Completed (see next chart)
- Remaining Simulation Tasks
  - Update Safe Haven, Maneuver Mode flight software (nearly identical to TOMS-EP)
  - Include earth sensor model & flight software
  - Update solar array pointing controller (based on STEP 0)
  - Include ephemeris propagator (based on Advanced Bus)
  - Implement NASA/LaRC MIMO controller

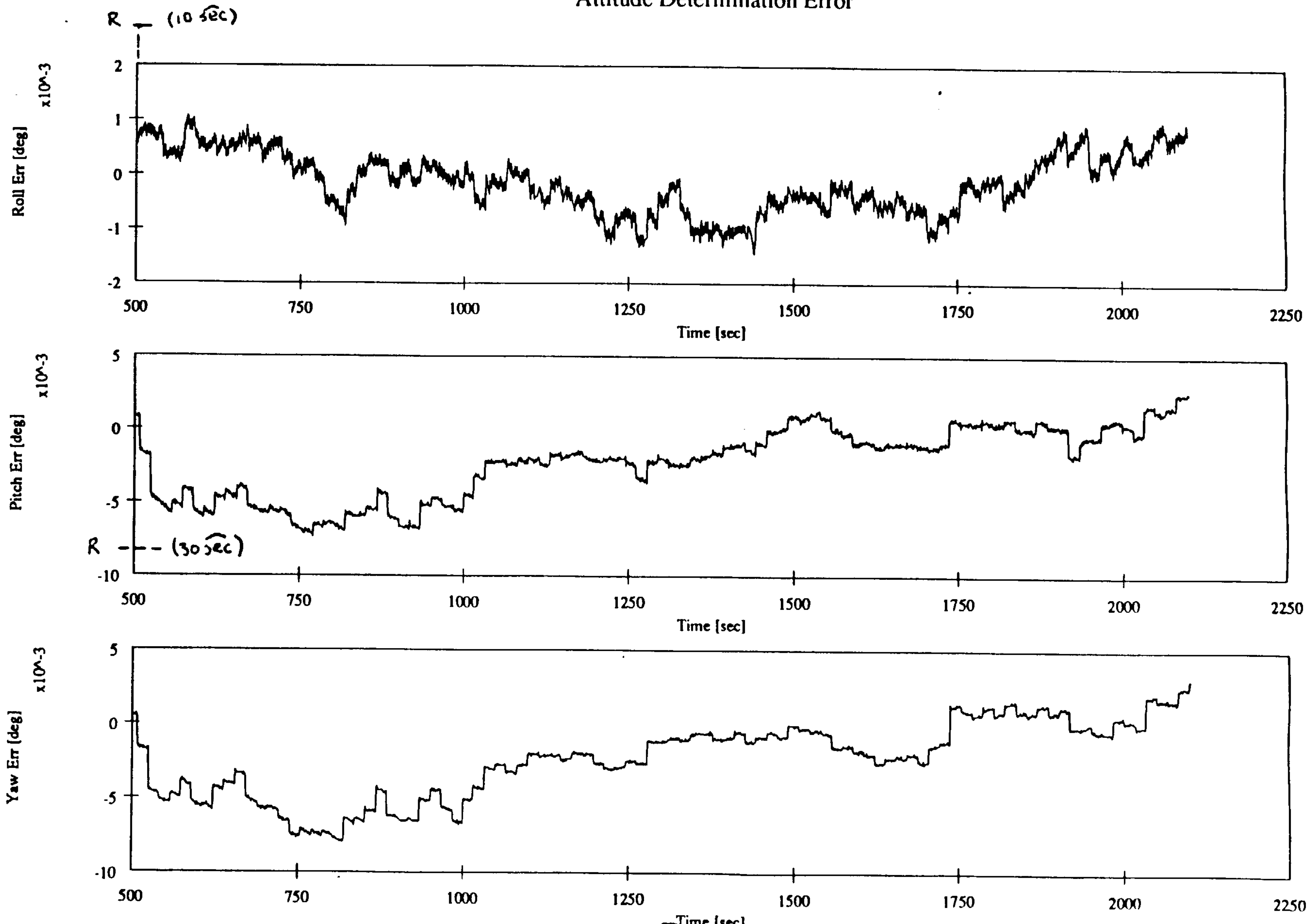
Safe Haven Mode

SSTI

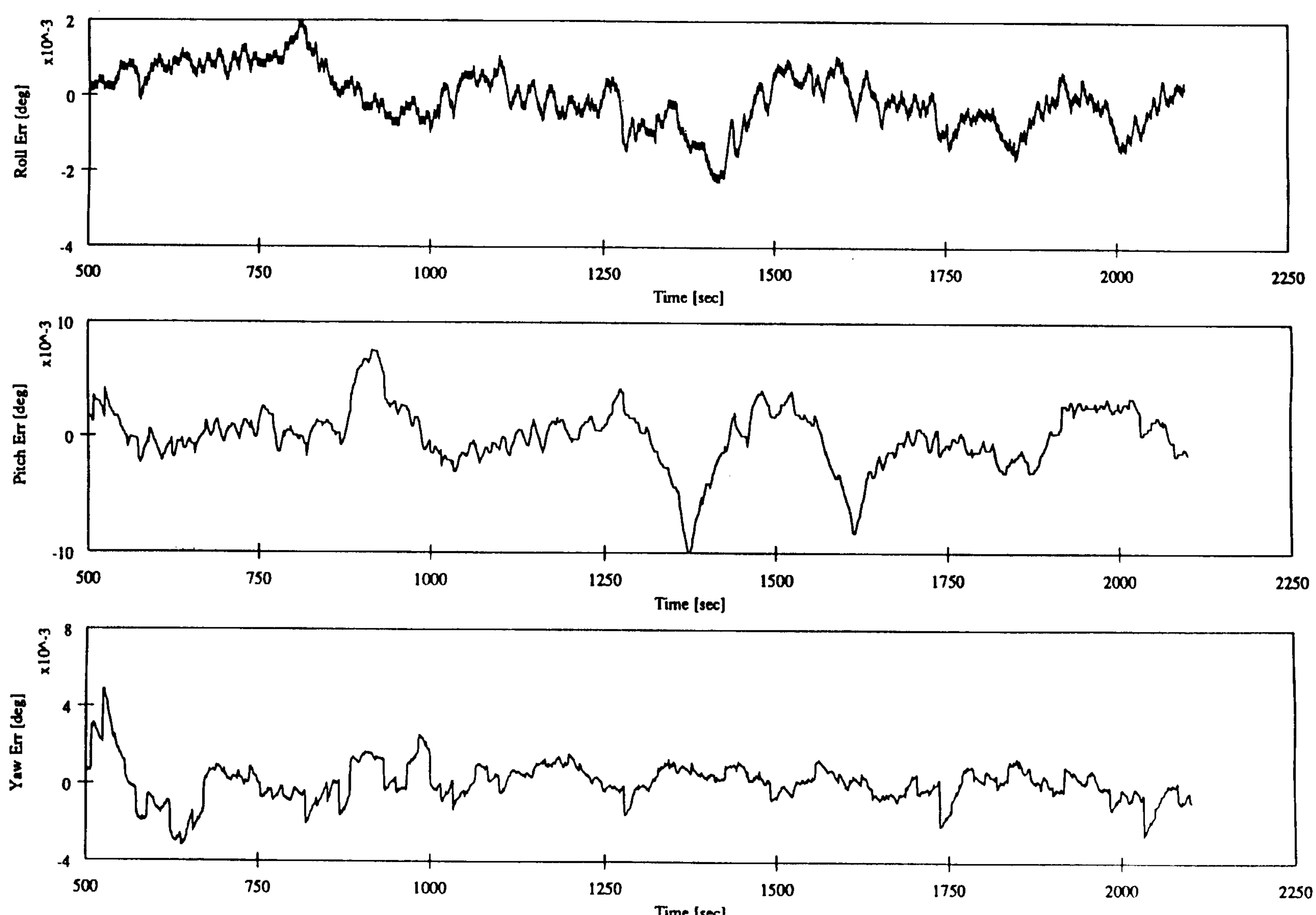
TRW

- Entered Upon Loss of Attitude Control, Processor Reset, or Undervoltage Condition
- Points Spacecraft and Solar Arrays at Sun Using Coarse Sun Sensors, and Backup Processor, Thrusters, SADAs (except bearings) and Gyro (second gyro is on to propagate attitude in background)
- Maximum Power Generated With Most Reliable Hardware
- Three Submodes Based on TOMS-EP Sun Mode:
  - Sun Acquisition - Pitch and yaw errors are controlled relative to the sun while the roll rate is uncontrolled. Preliminary calculations estimate acceptable roll rates for about one week
  - Sun-Referenced Hold - Second gyro is brought into the loop to zero rates about roll
  - Earth Search - Rotate about roll axis at 2 deg/sec to locate earth, with wheels spinning at bias speeds (zero net momentum)

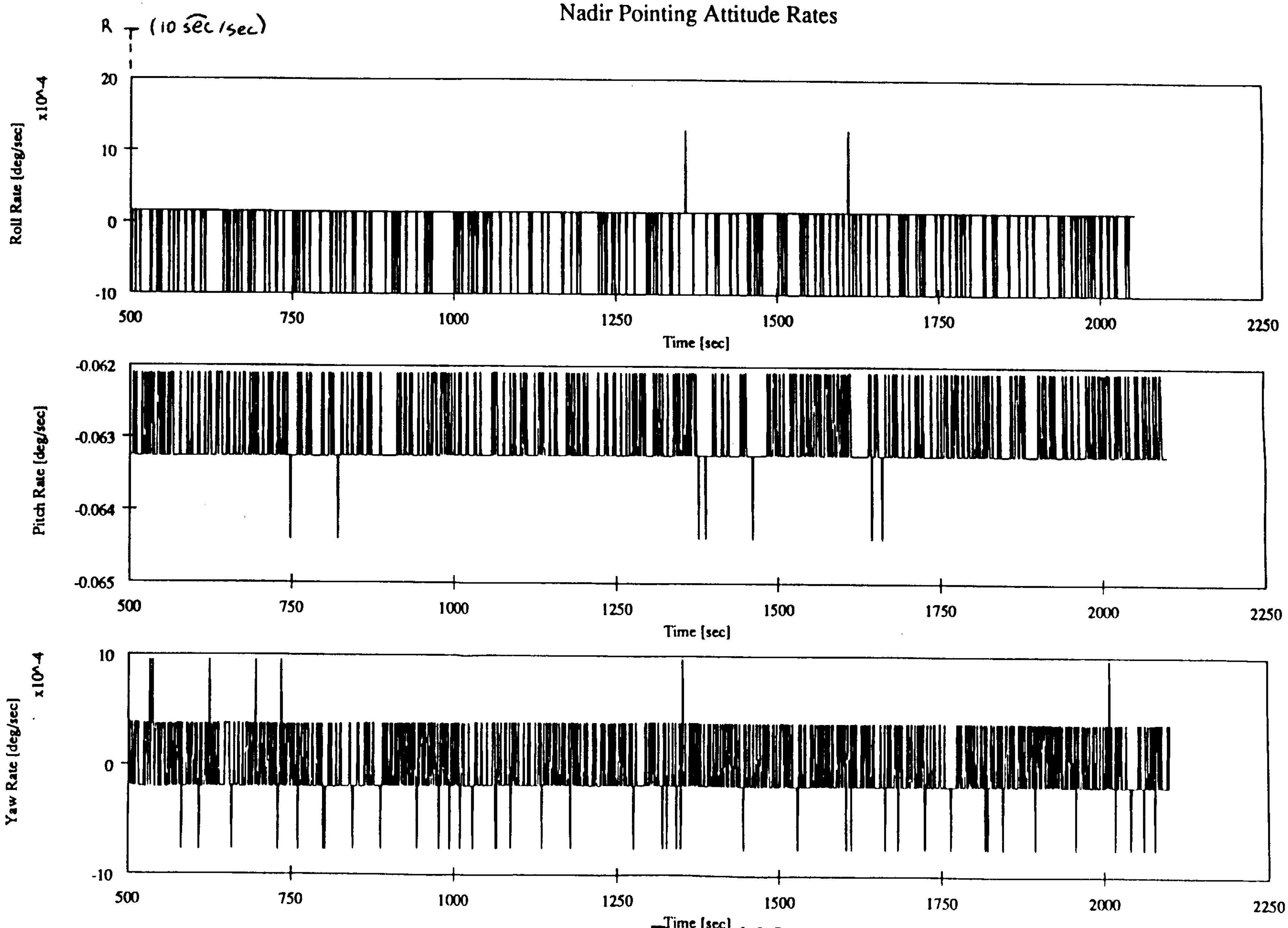
Attitude Determination Error



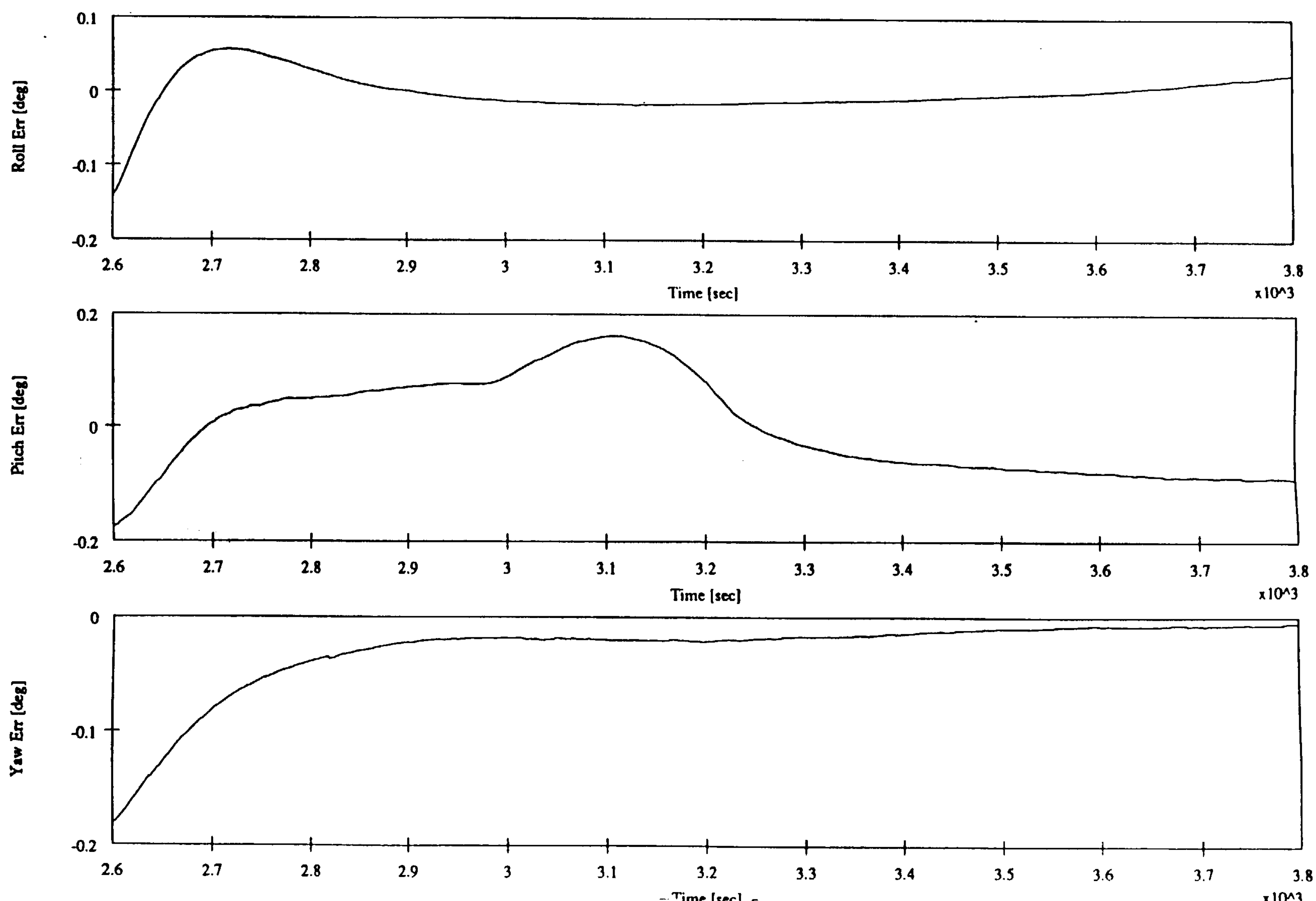
Nadir Pointing Control Error



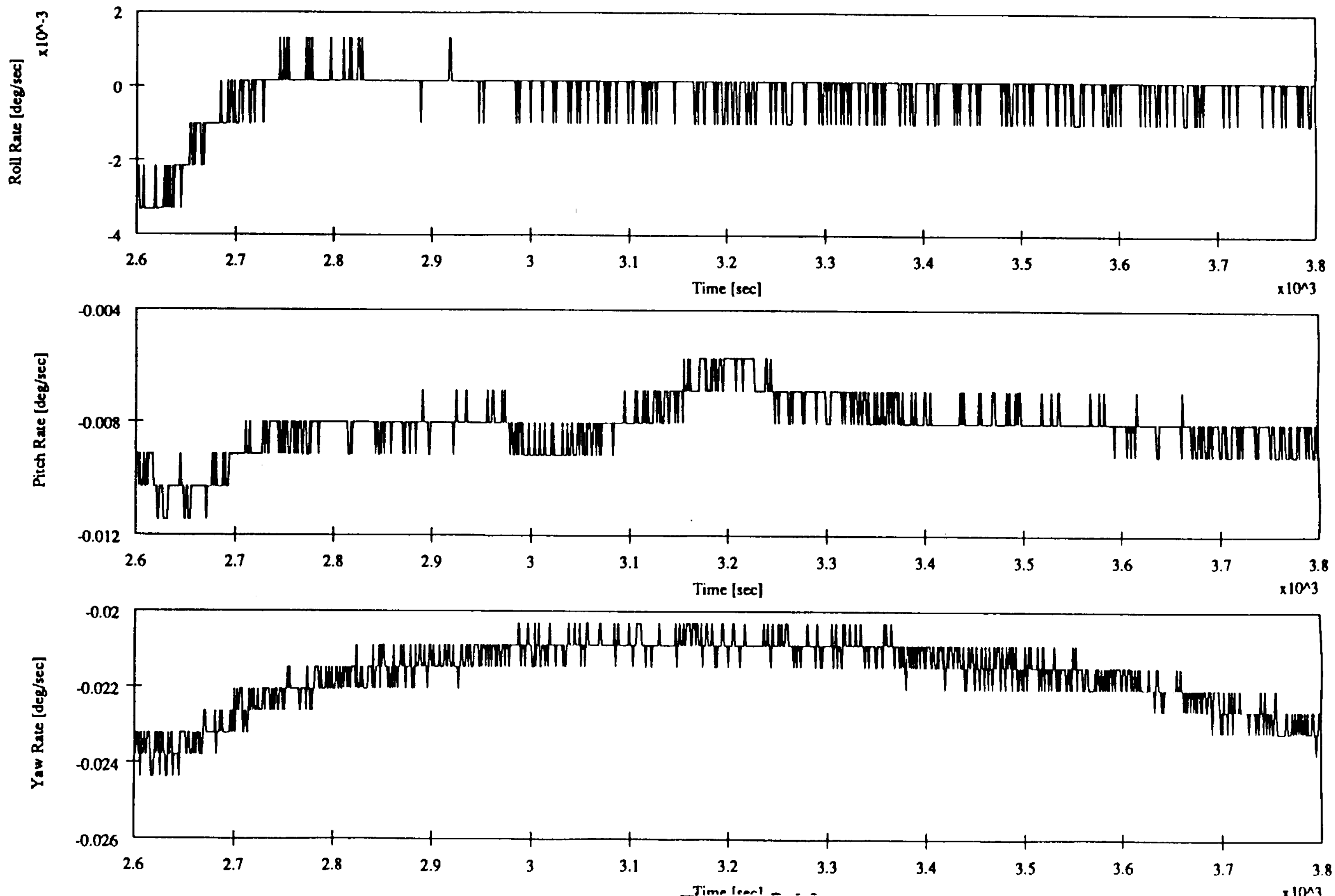
Nadir Pointing Attitude Rates



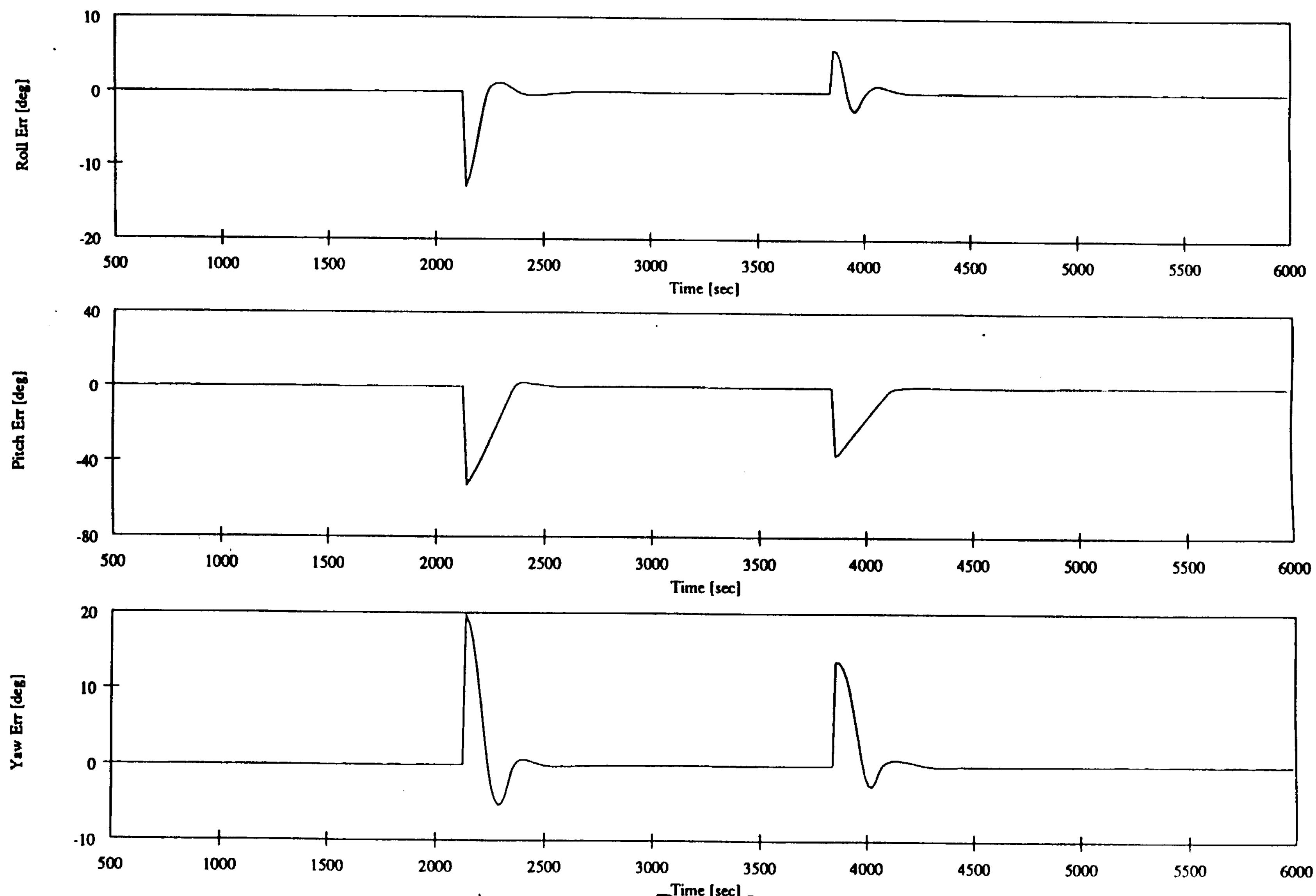
UCB Pointing Control Error



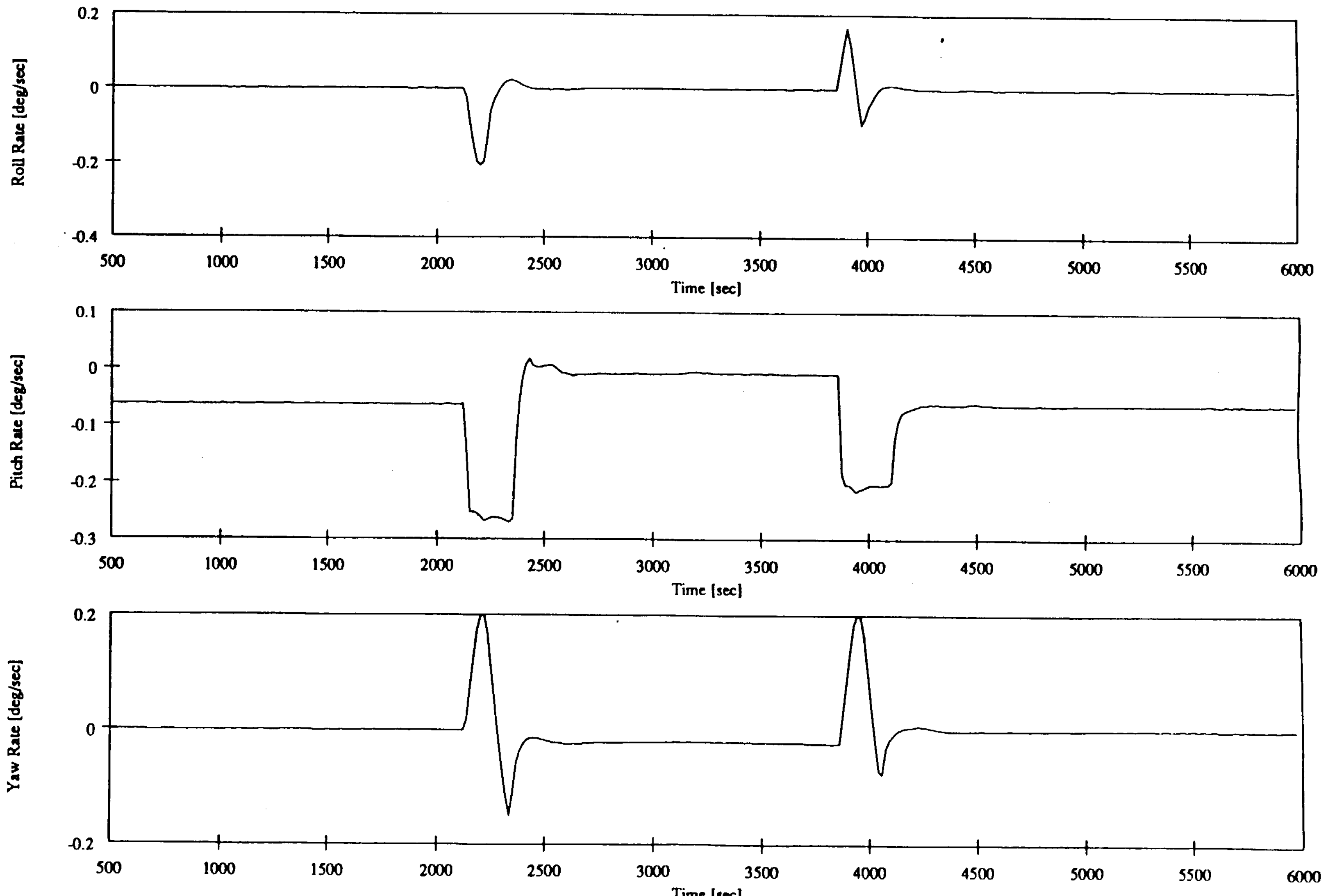
UCB Pointing Attitude Rates



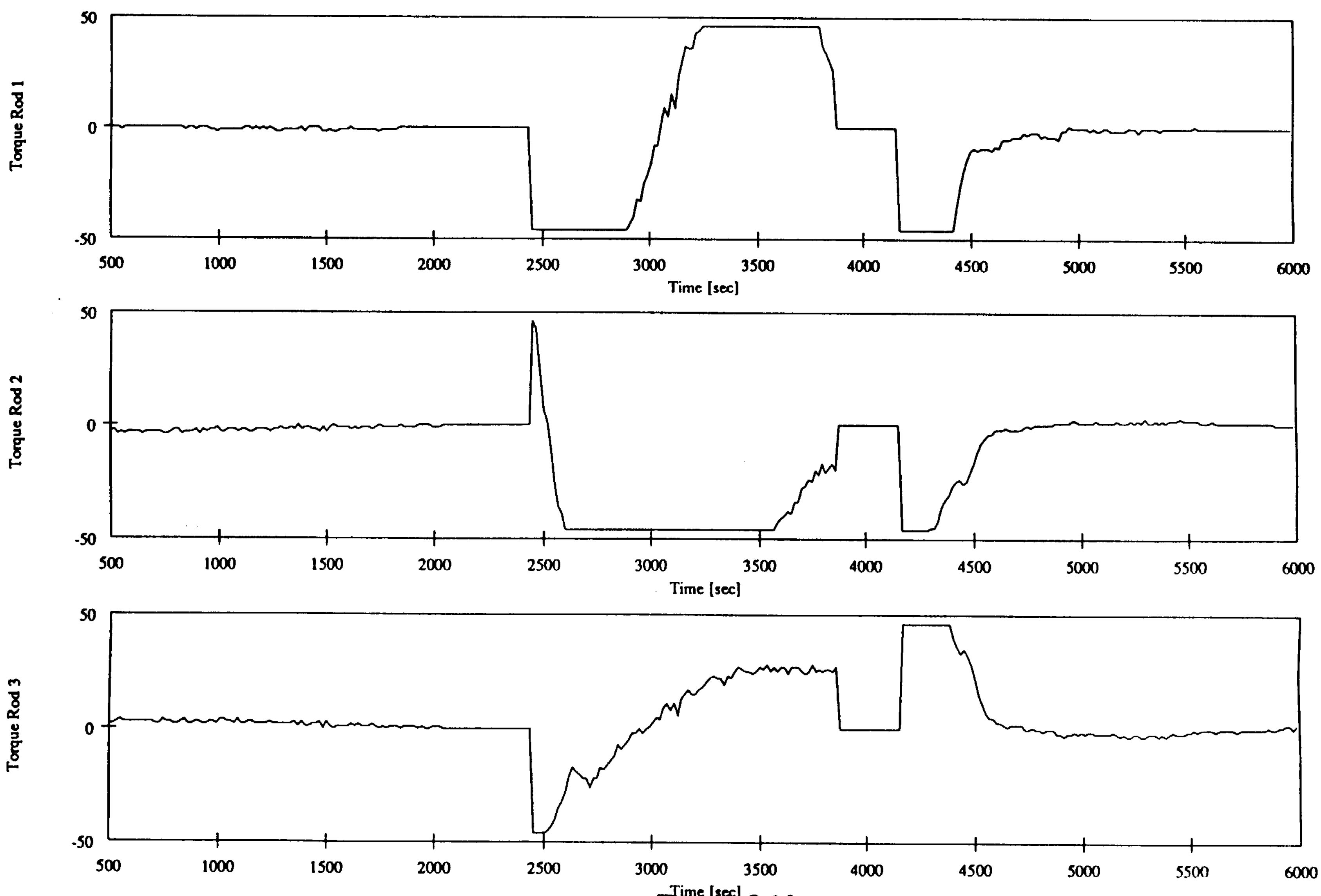
Attitude Control Error



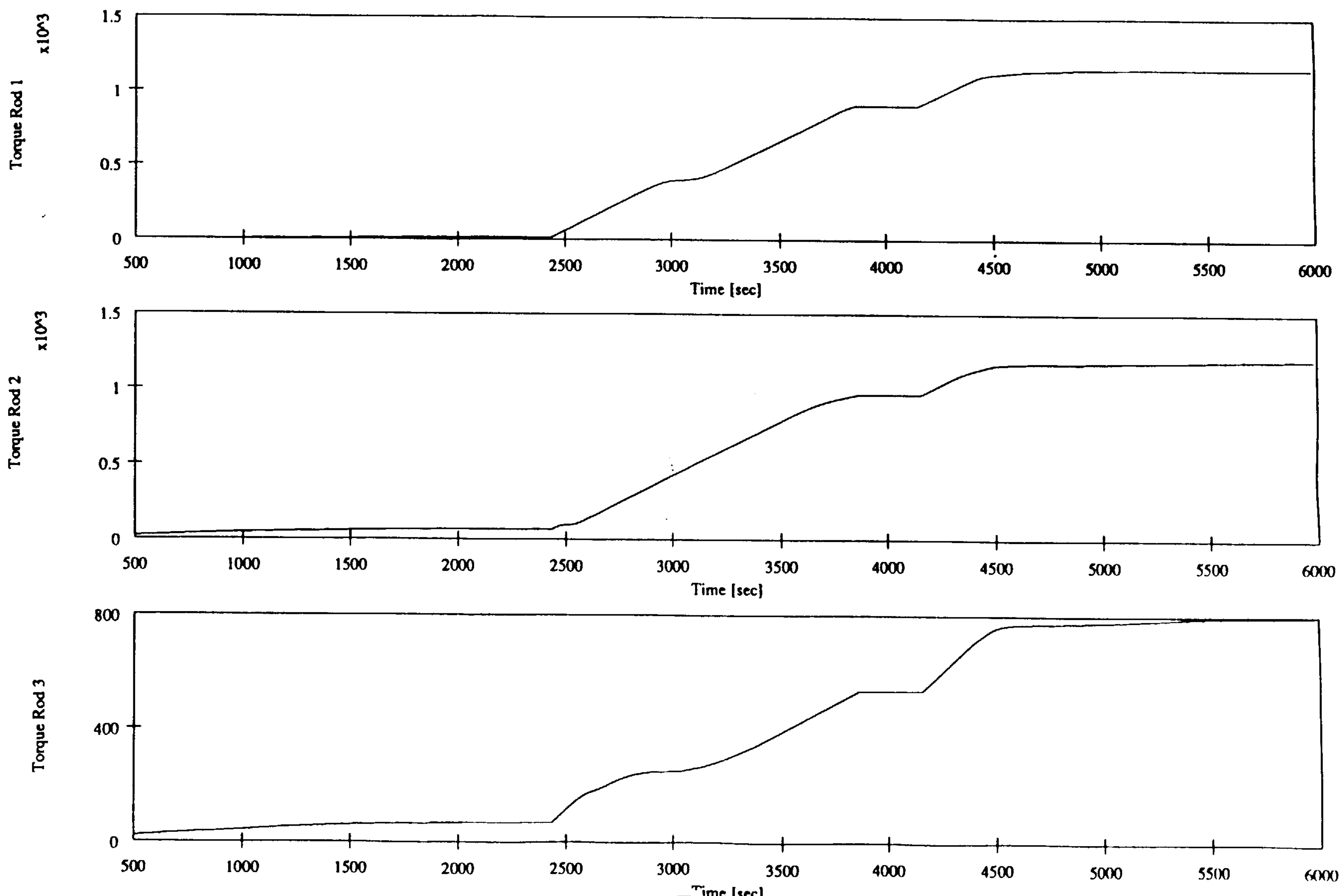
Attitude Rates



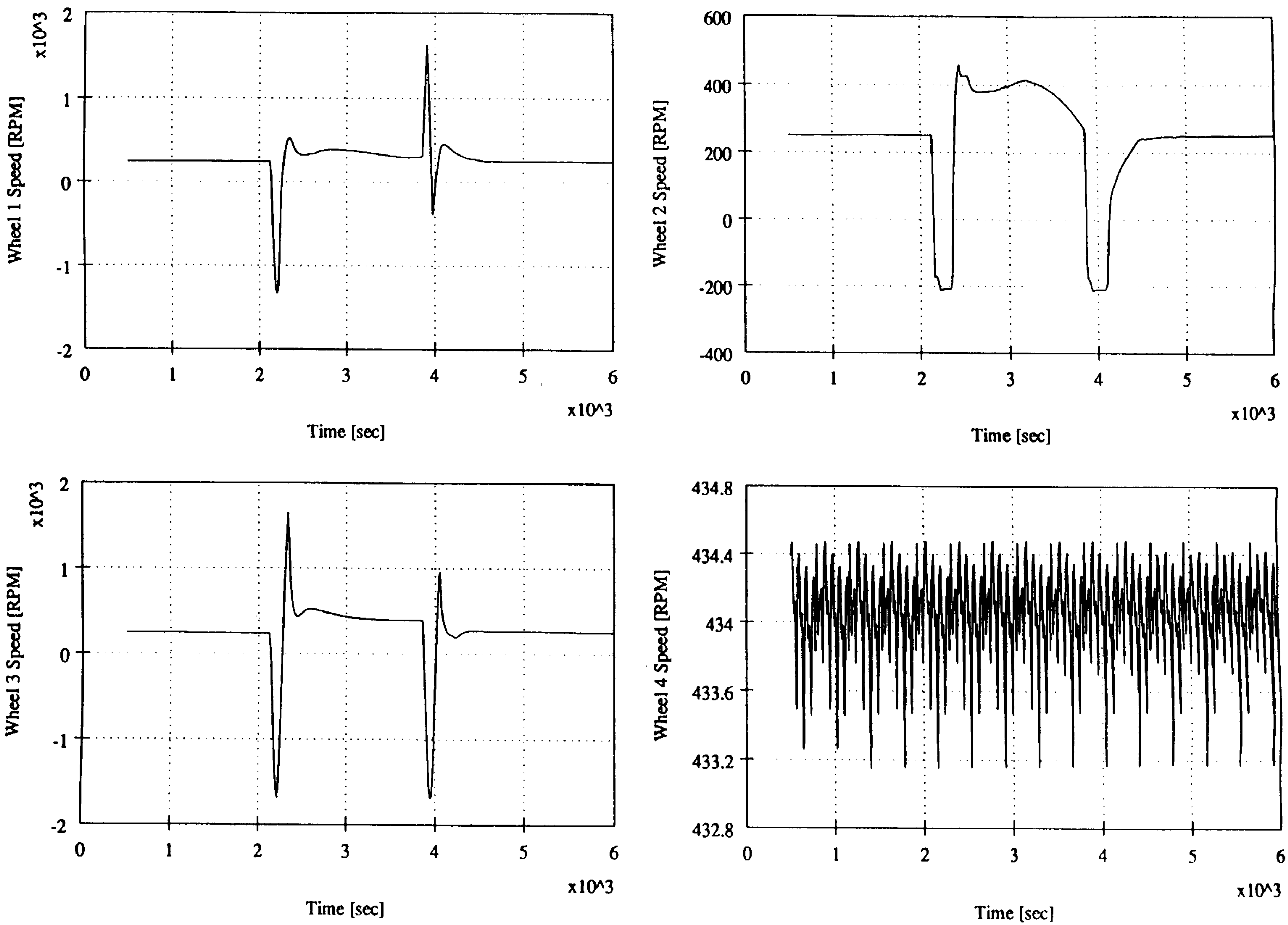
Torque Rod On Time



Cumulative Torque Rod On Time



Wheel Speeds



GN&C Subcontractor Status

- HDOS (Star Tracker)
  - Negotiations Complete
  - EQ. Spec. Under Revision
  - Drawings Complete, Except for NSTA Lightshade
  - Qualification Unit Complete End of June '95
  - Flight Unit Delivery in September
- Ideas (Magnetometer)
  - Four Month Schedule
  - Unit Identical to TOMS-EP TAM
  - Begin Negotiations This Month
- Kearfott (Gyros)
  - Under Letter Contract
  - Awaiting Final Quote From Kearfott
  - EQ. Spec. Complete
  - Drawing Released
  - Delivery in September

GN&C Subcontractor Status (Continued)

SSTI

TRW

- Barnes (Earth Sensors)
  - Awaiting Response on Legal Issues From Barnes
  - Have Reduced Schedule From 8 to 7 Months
  - EQ. Spec. Complete
  - Qual. Unit Complete Early February

- ITHACO (Wheels & Torqrods)
  - Under Full Contract
  - EQ. Specs. Completed, Awaiting Minor Revision to Wheel Spec.
  - Delivery in August
  - Drawings Completed

- Schaeffer Magnetics (Solar Array Drives & Electronics)
  - Under Letter Contract, Final Negotiations in Progress
  - EQ. Specs. Completed
  - Delivery in August

- Jackson & Tull (Valve Drive Electronics)
  - Parts on Order
  - Housing Design Modification Completed
  - Delivery in September

GN&C Test Approach

- Unit-Level Testing Performed at Vendor's Site
  - Thermal/thermal vacuum cycling
  - Random vibration
  - Full functional & performance
- Flight Software Testing Performed Initially on PCs/Workstations
  - Test all threads
  - Open and closed-loop
  - Utilize existing simulation as baseline
- Next Level of Testing Performed on Breadboard Processor
  - Test all threads open loop
  - Limited closed loop testing
  - Verify all commands and telemetry
  - Check out as many hardware interfaces with OBC as possible
  - Use breadboards and simulators for flight hardware

GN&C Test Approach (Continued)

SSTI

TRW

- Subsystem Testing With Flight Hardware Performed on Spacecraft
  - Tests flight harness as well
  - Complete hardware/software interface checkout
  - End-to-end open loop testing
  - Polarity testing

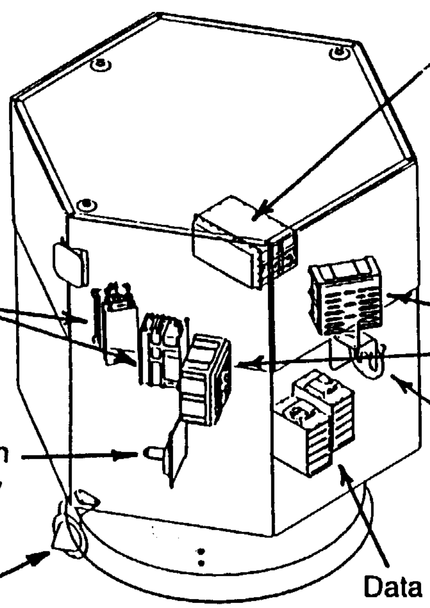
- Continue End-to-End and Polarity Testing Throughout System and Environmental Test Phase
  - Exercise processor under worst-case loading conditions
  - Look for differences (e.g. wheel drag torques) from baseline

SPACECRAFT BUS

Data Management Subsystem

R. Almeida

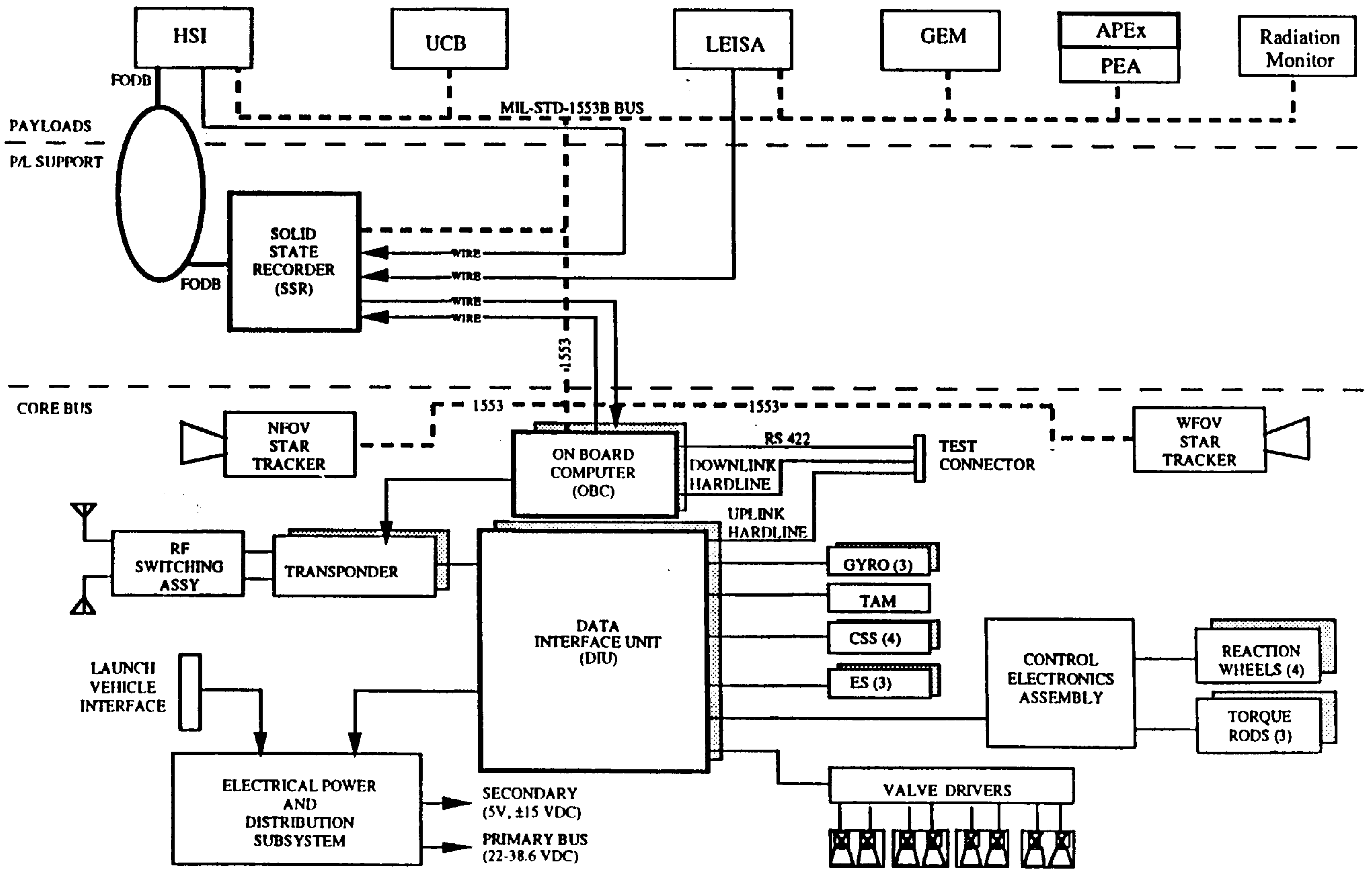
Data Management Subsystem



DMS Equipment Locations

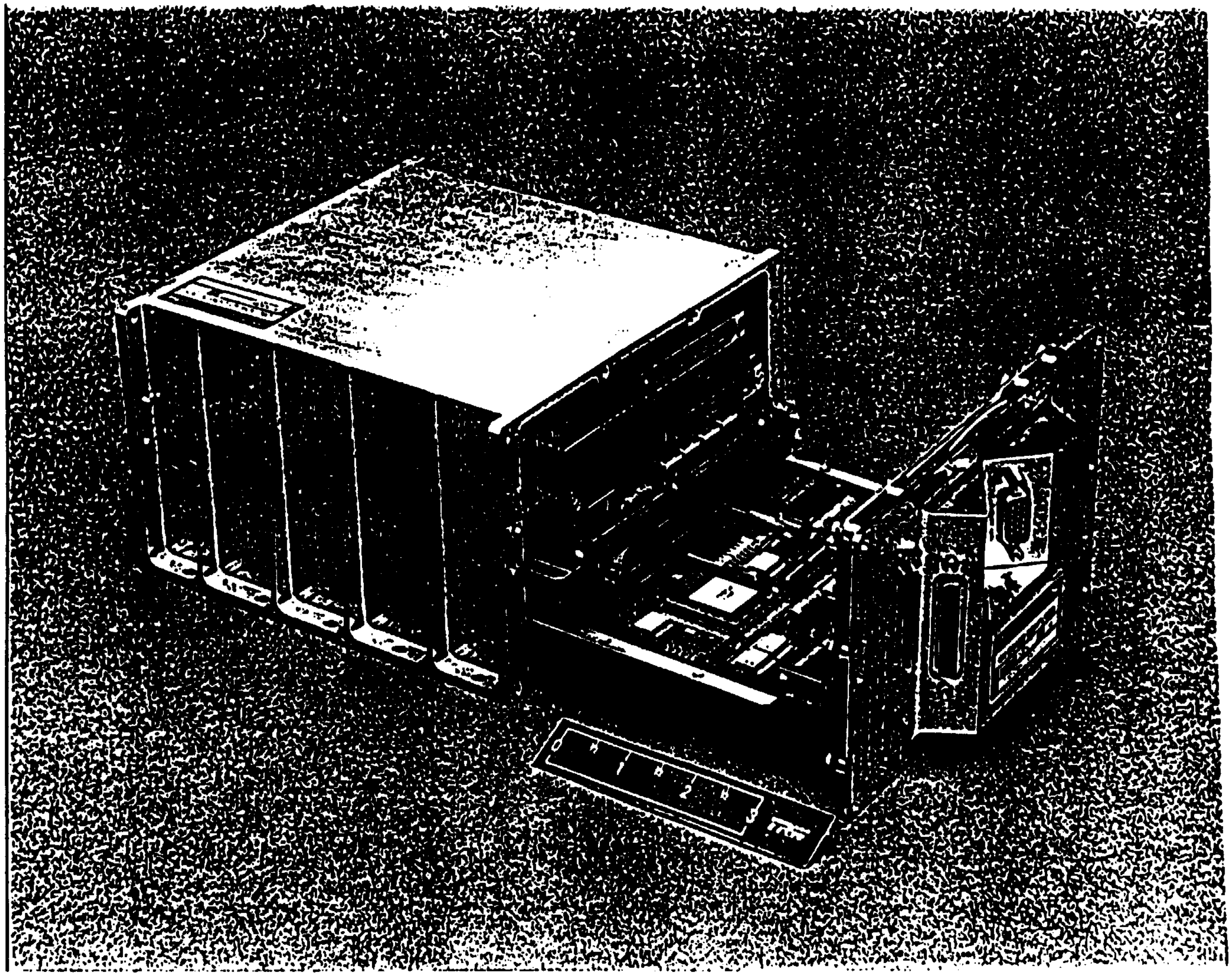
- R3000 On Board Computers
  - $\geq$ 8 MIPS at 16.384 MHz
  - 2 MByte SRAM, 1 MByte EEPROM
- Data Interface Units
  - TT&C, GN&C, OBC and EPDS interface functions
  - Discrete and analog command generation & processing
  - Fault monitoring
- 4 Gigabit Solid State Recorder
  - 440 MBPS data rate
  - Real time data sorting
- Fiber Optic Data Bus
  - 440 MBPS data rate
- 1553B Bus Controller
  - Command distribution and data acquisition
- S-Band Transponders
  - 5 watt RF power output, GSTDN/DSN compatible
  - 2 kbps uplink command rate
  - 8 kbps or 2.048 mbps downlink telemetry,
  - Convolutionally encoded (NASA Std r=1/2, k= 7 Viterbi)
- RF Switching Assembly
  - Omni or nadir-directed RF transmission
  - Transponder transmitter selection
- S-Band Antennas
  - $\geq$ 85%spherical coverage for receiving and transmitting
  - Shaped pattern enhances gain at beam edges
- Estimated Weight: 22 Kg
- Orbit-average Power: 61 W

Data Management Subsystem Interface



Rev. DMS Interface
DMS.ICDA2.1/19/95

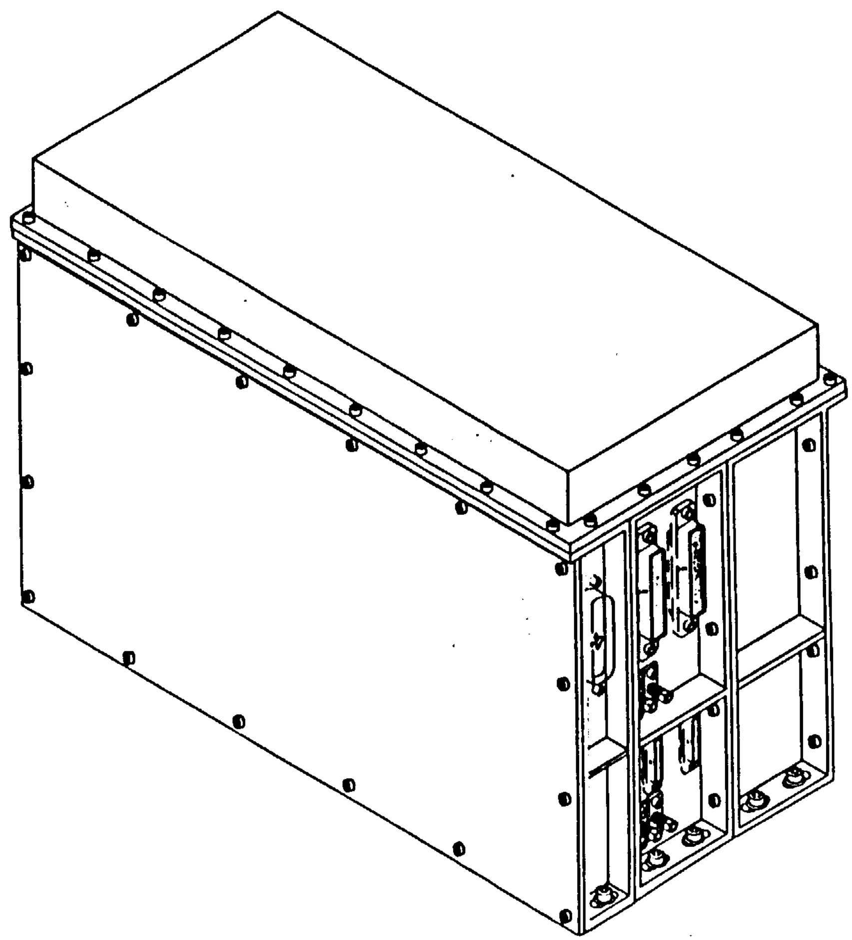
On Board Computer



SSTI

Solid State Recorder

TRW



SSR
SIZE: 11.26L X 5.0W X 7.5H
WEIGHT: 12.0 LB EST.

DMS.ICDA2.1/19/95

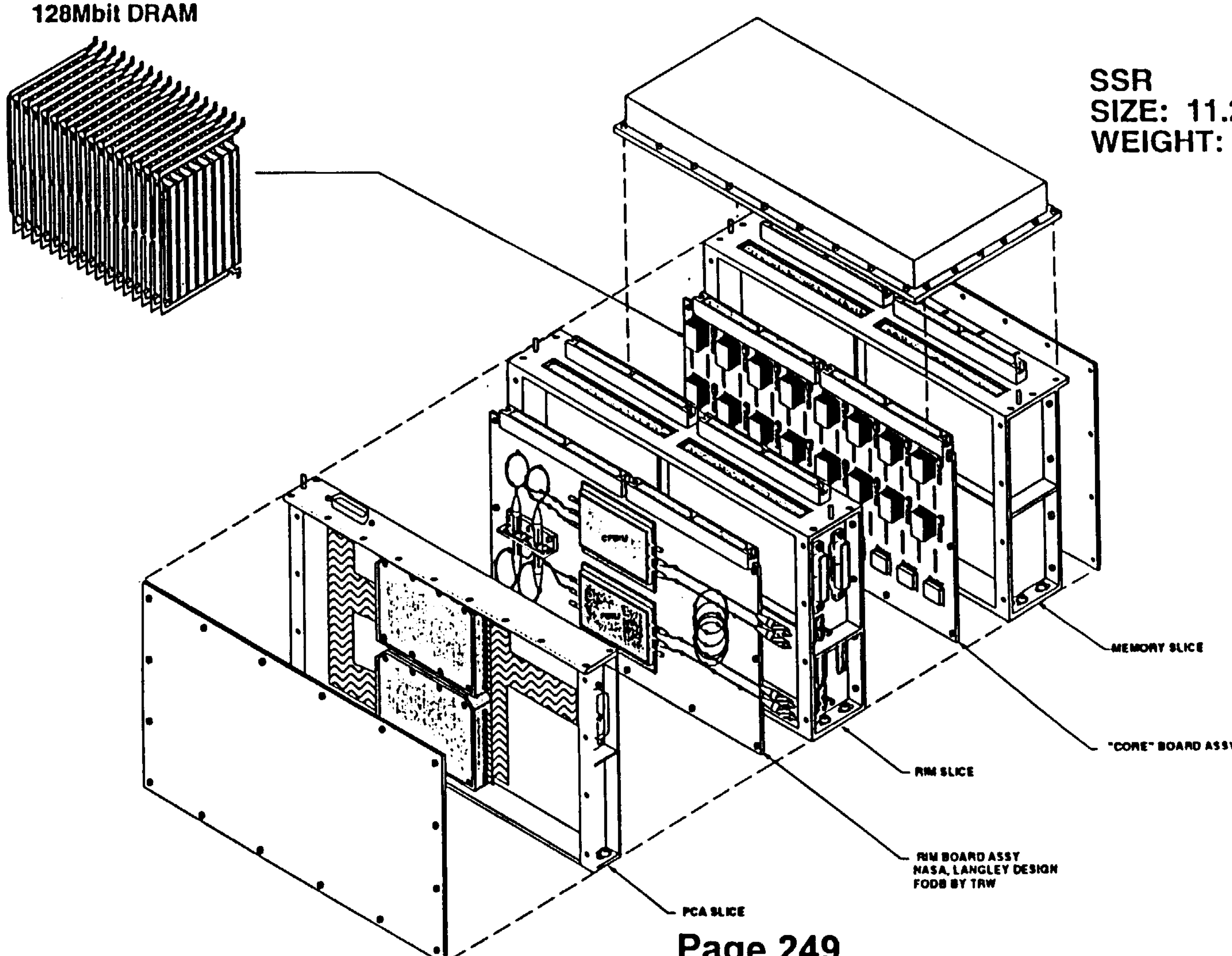
Solid State Recorder

SSTI

TRW

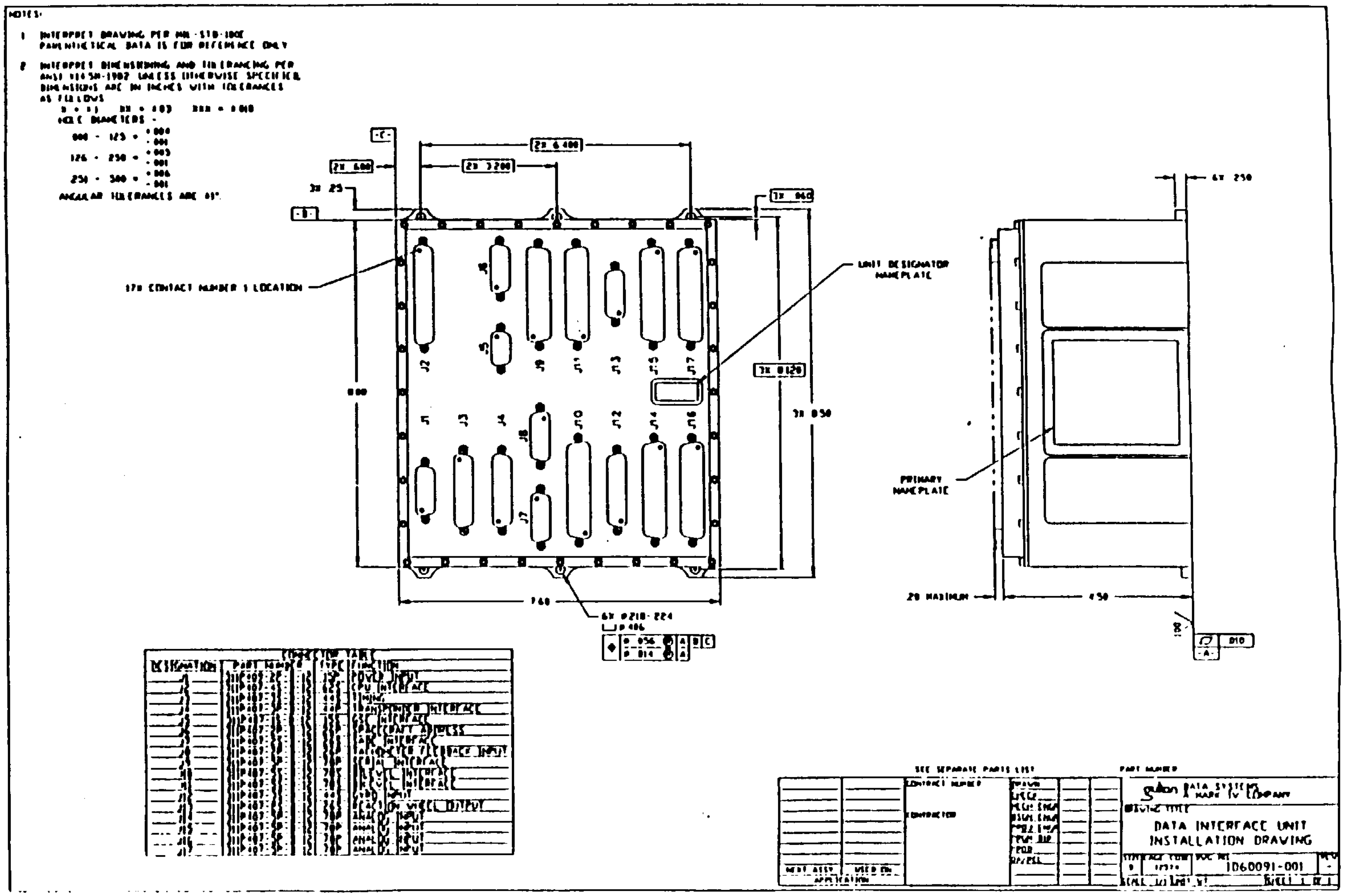
STAKEK
128Mbit DRAM

SSR
SIZE: 11.26L X 5.0W X 7.5.0H
WEIGHT: 12.0 LB EST.



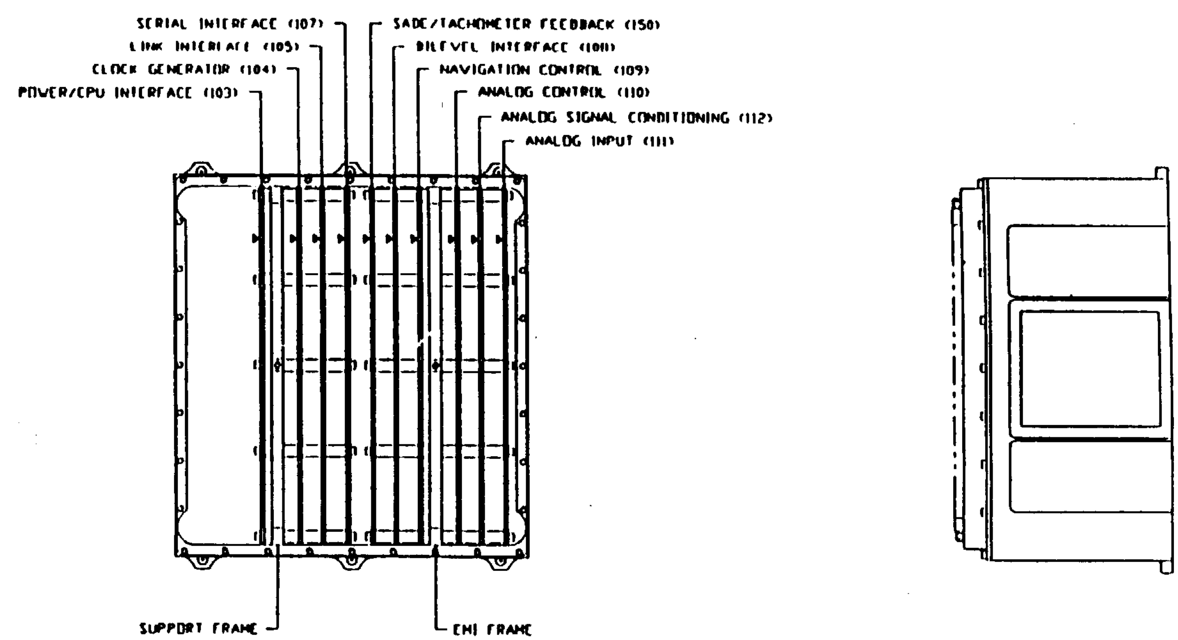
DMS.ICDA2.1/19/95

Data Interface Unit Layout



3.4

Data Interface Unit Layout



3.8

SSTI

Size, Weight & Power Summary

DMS Unit Name	Size (inches) Lgth xWdth xHt	Weight (Kg) Incl Rdndcy	Power (W) Orbital Avg
On Board Computer	6.7 x 6.8 x 4.0	6.4	39.6
Solid State Recorder	11.3 x 5.0 x 7.5	5.8	21.1
Data Interface Unit	7.6 x 8.0 x 4.5	5.3	9.5
RF Assembly	n/a	1.6	7.6
Transponder	n/a	8.4	3.9 *
Antenna	n/a	.7	-
APEx	6.0 x 4.0 x 1.0	.6	5.0

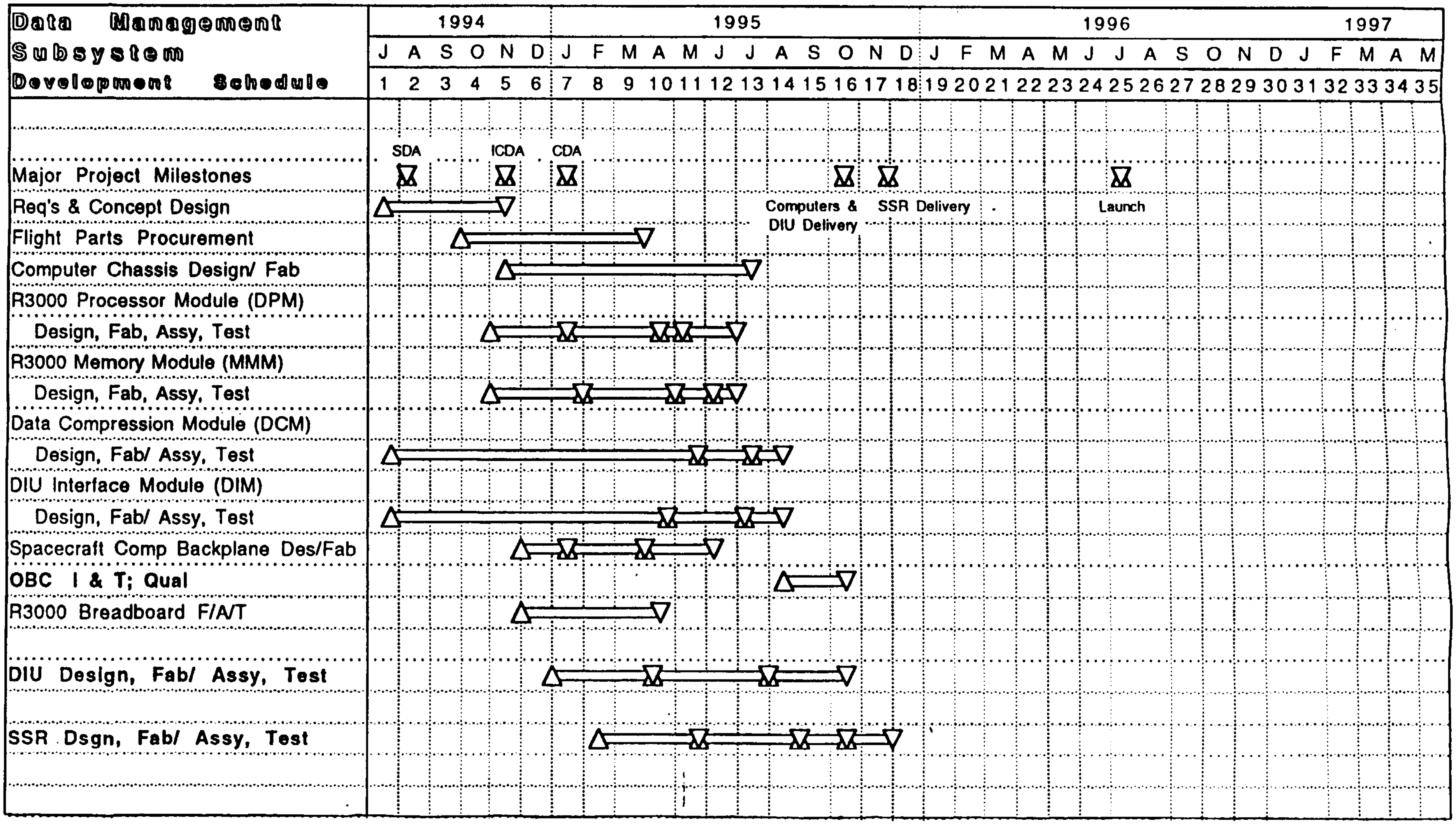
* Assumes 10% duty cycle

Unit, Board, Parts Count Summary

DMS Unit Name	Units Per DMS	Boards Per Unit *	Parts Count IC	Parts Count Discrete	Misc
On Board Computer	2	5	129	295	DC/DC Conv
Solid State Recorder	1	5	135	352	DC/DC Conv
Data Interface Unit	2	10	393	972	
RF Assembly	1	n/a	n/a	n/a	
Transponder	2	n/a	n/a	n/a	
Antenna	2	n/a	n/a	n/a	
APEx	1	1	20	40	

* Includes Motherboard

DMS Development Schedule



DMS.ICDA2.1/19/95

SSTI

DMS Requirements vs. Capabilities vs. Verification

TRW

Data Management Subsystem Overall Requirements

Requirement	Source	Capability	Verification
Spacecraft processing and control	System	OBC provides uplink/downlink data formatting and rate buffering; spacecraft command, control and telemetry processing; payload experiment control; low rate data and control bus master	Test, Analysis, Inspection
Spacecraft core subsystem interconnect	System	DIU links the OBC to the GN&C, EPDS, and TT&C units	Test, Analysis
Mass Data Storage	System	4 Gbit (BOL) Solid State Recorder	Test, Analysis, Inspection
Experiment Data Compression	System	Lossless and Lossy data compression capability. SSR used for mass data storage	Test, Analysis
Tracking, Telemetry & Command	System	Transponder, RF Assembly and S-band antennas support 2 Kbps uplink; 2.048 Mbps and 8 Kbps downlink	Test, Analysis
Fault Tolerant Architecture supports 5year mission goal	System	OBC/DIU are redundant pairs; SSR has I/O redundancy with graceful degradation on memory array; TT&C assemblies are dual redundant. Redundancy management based on proven TOMS architecture	Analysis, Inspection

SSTI

DMS Requirements vs. Capabilities vs. Verification

TRW

Environmental and Reliability Requirements

Requirement	Source	Capability	Verification
Operate in LEO, circular, sun synchronous radiation environment. 2Krad Total Dose parts (given 150Mil Al shielding). Latchup immune parts.	Environmental Specification	>5Krad Total Dose parts. No Latchup.	Analysis
A single event upset (SEU) shall not cause lossof the Mission or Spacecraft	Spacecraft specification	SEU Tolerant Processor and Memory Designs. Built in SSR EDAC and memory scrubbing provide BER > 10-9	Analysis
Fault tolerant architecture	Derived	Redundant OBC, DIU, Transponder, RF Switching Assy, S-band Antennas, and SSR interfaces. SSR memory array supports graceful degradation. Independent watchdog timer can initiate transition to contingency mode if primary processor fault detected.	Analysis
Five Year Reliability GOALS: OBC = .905 SSR = .98 DIU = .88 (single unit)	System	Reliability at 5 years: OBC = .908 SSR = .98 DIU = .88 (single unit)	Analysis

DMS Requirements vs. Capabilities vs. Verification

OBC Performance and Architecture Requirements

Requirement	Source	Capability	Verification
32 bit processor architecture with 2MIPS performance	Software, Derived	MIPS R3000/R3010 processor design. >8 MIPS operating at 16.384 MHz. Modular memory mapped architecture. 16 Kwords instruction and data caches	Test, Analysis, Inspection
3 programmable S/W timers	Software	5 programmable S/W timers	Test
512K Words (2 Mbytes) Main Memory with Error Detect and Correct	Software	512K x 32 SRAM with separate standby (3V) power for memory retention when computer is OFF. Hardware implemented Single Error Correct; Double Error Detect on memory read operations	Test
256K words (1 Mbyte) of nonvolatile memory which can be written into while in flight	System, Software	256K x 32 EEPROM programmable in flight	Test
Provide lossless data compression. 256 samples per packet. 8, 12, 13 bits per sample	System, Derived	Lossless data compression hardware (Rice Algorithm). Lossy data compression performed in software. Supports up to 1024 samples per packet; 4 - 14 bits per sample (programmable)	Test, Analysis

DMS Requirements vs. Capabilities vs. Verification

SSTI

OBC Interface Requirements

Requirement	Source	Capability	Verification
DIU Interface:			
OBC will interface to DIU through existing 8086 bus within DIU design	Derived, TOMS SP Specification	DIU interface translates R3000 timing to 8086 timing. Provides 8 address lines and 16 data lines	Test
SSR Interface:			
SSR to OBC serial data transfer rate of 4.096Mbps. OBC to SSR serial data transfer rate of 4.096Mbps. DMA capability for transferring data to/from OBC write/read ports	Derived, Change Control Board Action #3	Two unidirectional 4.096 Mbps serial interfaces provide read and write capability. Handshake signal used to regulate SSR to OBC data transfer. DMA capability for transferring data to/from OBC write/read ports	Test, Inspection
OBC will receive SSR data in 1920 bit increments (2 SSR words = 60 x 32 bit words) only.	Derived	8K byte FIF0 used to buffer data	Test, Inspection
Transponder Interface:			
Provide interface to transponder for data and telemetry downlink. Support 2.048 Mbps and 8.0 Kbps downlink rates	System	OBC outputs continuous data and clock transmission to transponder when TLM transmit is enabled. Both 2.048 Mbps and 8.0 Kbps serial data transfer is provided to the transponder for high rate and low rate downlink. DMA is used to feed OBC output port. Power Control Unit provides control bilevels to the transponder.	Test
Downlink data formatting	Derived	Data formatting is performed in software	Test

SSTI

DMS Requirements vs. Capabilities vs. Verification

Integration and Test Interface			
Downlink hardline interface	Software, Integration and Test	Separate test interface provides low rate and high rate downlink data	Test
Provide interface to OBC for S/W and unit development and test	Software, Integration and Test	Dual RS232 serial ports with RS422 differential interfaces	Test
Control and Telemetry I/F			
Provide spacecraft command, telemetry and low rate data interface	System	MIL-STD-1553B Bus Controller	Test

SSTI

DMS Requirements vs. Capabilities vs. Verification

SSR Performance and Architecture Requirements

Requirement	Source	Capability	Verification
Provide inteconnectivity and mass data storage between the OBC and payload experiments	System, Change Control Board Action #3	Comply	Test, Analysis
2 Gbit memory capacity	System	4 Gbit BOL with graceful degradation to 2 Gbit EOL	Test, Analysis
Software configurable memory partitions	System, Software	Software selected active and configured memory partitions. Active partitions support real time data sorting and binning. Minimum memory partition is 1920 bits. Maximum memory partition is max available memory. Available partitioning is as follows: 3 active partitions for HSI 1 partition for LEISA 1 partition for OBC 32 active partitions for 1553	Test
Simultaneous data record and playback	System, Software	Simultaneous read and write capability. Only one data write (to SSR) port active at a time. 1553 interface port can collect data in internal buffer simultaneous with SSR memory write	Test
Single fault tolerant architecture	System	Primary and redundant interface boards with separate power converters. Common memory array with graceful degradation	Test, Analysis

DMS Requirements vs. Capabilities vs. Verification

SSTI

SSR Interface Requirements

Requirement	Source	Capability	Verification
Provide experiment data interfaces for data collection	Derived	Selectable write interface (only one active at a time). Data interfaces are: - Fiber optic data bus (FODB) from HSI to SSR (serial optical data) - Hardwire interface for HSI to SSR (32 bit parallel) - Hardwire interface for LEISA to SSR (4bit multiplexed data) Additionally, OBC and 1553 interfaces	Inspection, Test
Provide OBC read and write interfaces for data processing, compression and downlink	Derived	- Hardwire interface for OBC to SSR (serial interface) - Hardwire interface for SSR to OBC (serial interface)	Inspection, Test
Provide command and telemetry (low rate data) read / write	Derived	1553 Remote Terminal interface	Test
Control Fiber Optic Data Bus (FODB)	System	FODB ring controller as well as read and write capability. Write capability used for test	Test, Analysis

DMS Requirements vs. Capabilities vs. Verification

Data Interface Unit (DIU) Performance Requirements

Requirement	Source	Capability	Verification
Spacecraft Command Uplink	System	2 Kbps uplink rate 90 valid commands 48 bits/command 10 locally decoded commands	Analysis, Test
Fault Monitoring	System	Independently powered watchdog timer initiates redundancy switchover. .5 sec heartbeat	Test
Spacecraft Analog Telemetry	Derived	122 channels 12 bit ADC at 300 μs conversion time 3 gains - 1, 2 and 4 5 offsets +/-5V, +/-2.5V, OV	Test
Spacecraft Discrete Commanding	Derived	33 bilevel outputs	Test
Spacecraft Discrete Telemetry	Derived	48 bilevel inputs	Test
Spacecraft serial CMD/TLM	Derived	4 serial commands/ telemetry to EPDS & ACDS 204.8 Kbps rate	Test
Tach feedback on four solar panel motors	Derived	0-7000 RPM Integrated over a 1.024 second period	Test

SSTI

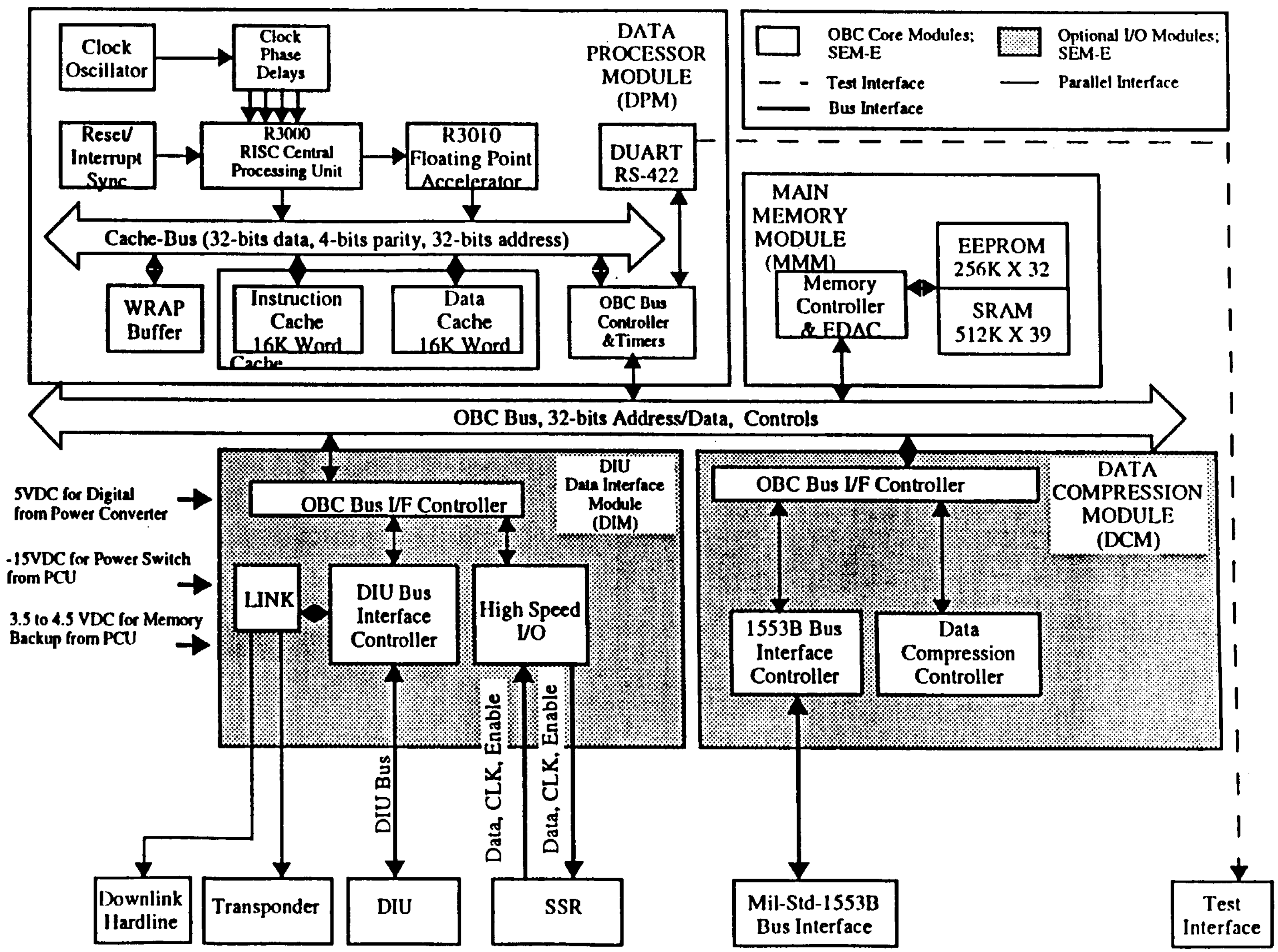
DMS Requirements vs. Capabilities vs. Verification

TRW

Data Interface Unit (DIU) Interface Requirements

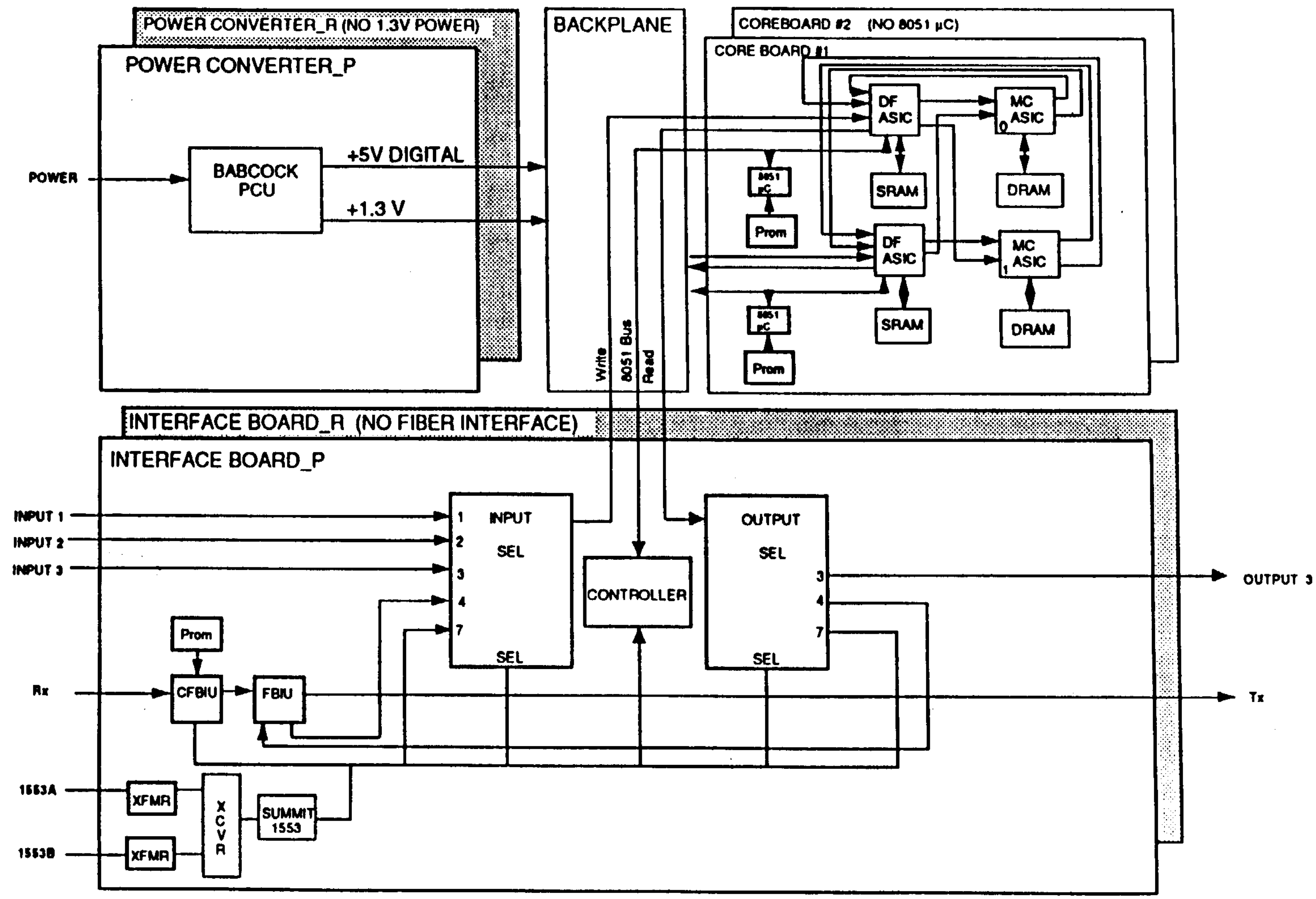
Requirement	Source	Capability	Verification
OBC R3000 Interface	System, Derived	8086 timing at 4.096 MHz Memory mapped I/O to R3000 256 mapped I/0 registers Reset interface to DIU 8 interrupt lines incl minor frame (32 ms) 32 bit to 16 bit data path conversion	Test, Analysis
EPDS Interfaces	System, Derived	3 serial interfaces (redundantly cross-strapped) at 204.8 KHz 13 bilevel inputs to DIU (cross-strapped) 10 bilevel output to PCU (cross-strapped) 4 analog inputs to DIU (cross-strapped)	Test
SADE Interfaces	System, Derived	4 Tach feedback channels 4 position feedback channels (cross-strapped) 6 bilevel outputs from DIU	Test
OAS Interfaces	System, Derived	14 Analog temp measurements 1 Analog pressure measurements 3 bilevel	Test
ACDS interfaces (including GYRO, VDE, MDE, Torque Rod, Earth Sensor and TIM interfaces)	System, Derived	72 Analog inputs 1 Serial at 204.8 KHz to VDE 10 Bilevels(4 to MDE, 6 to Torque Rods) 12 bilevel pulse inputs from GYRO	Test
Uplink hardline interface	Software, Integration and Test	Separate test interface provides uplink data port	Test

On Board Computer Block Diagram



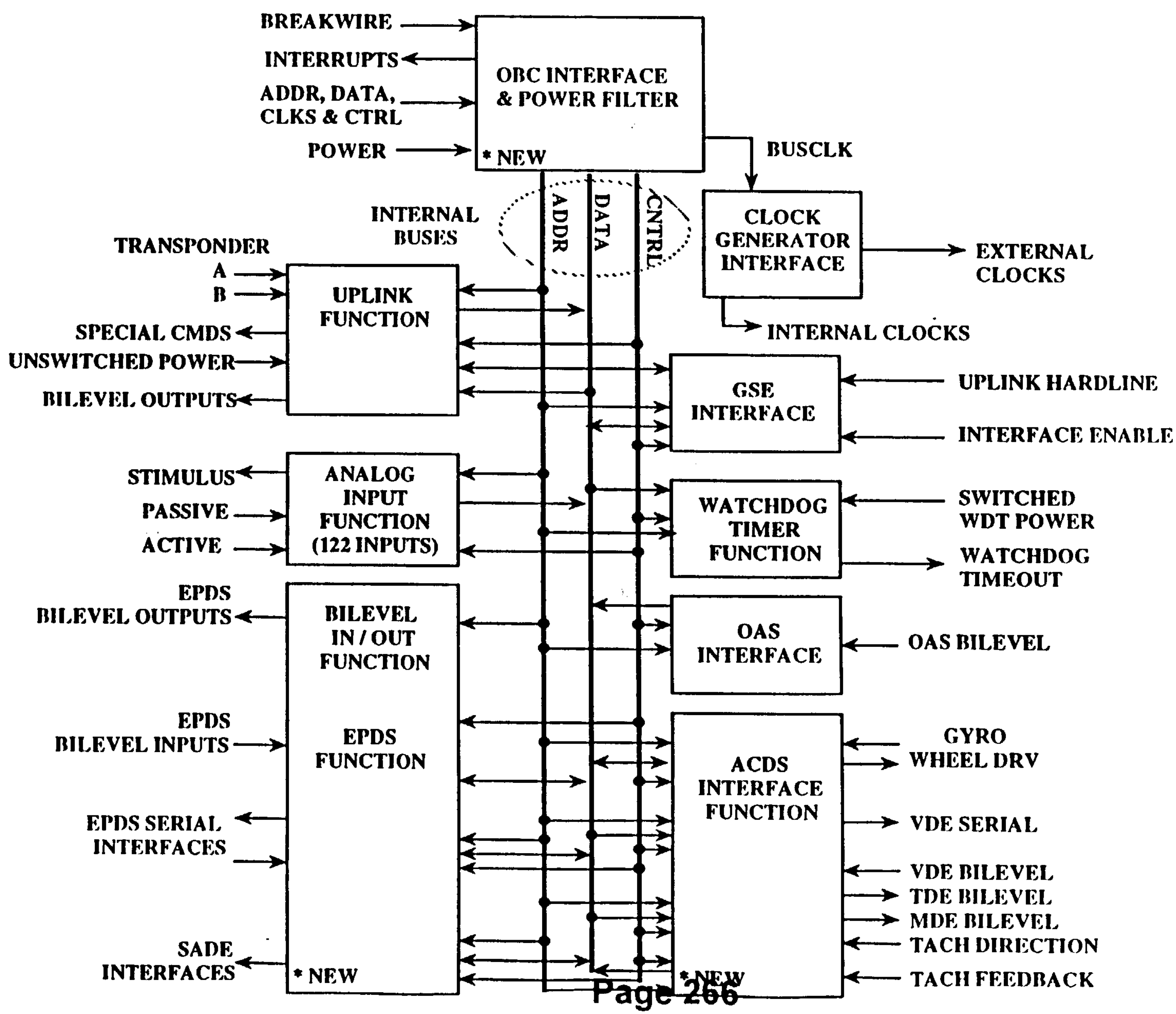
ICDA2 OBC Blk Diagram
DMS.ICDA2.1/19/95

Solid State Recorder Block Diagram



SSR BLK ICDA2
DMS.ICDA2.1/19/95

DIU Block Diagram



ICDA2 DIU Blk Diagram
DMS.ICDA2.1/19/95

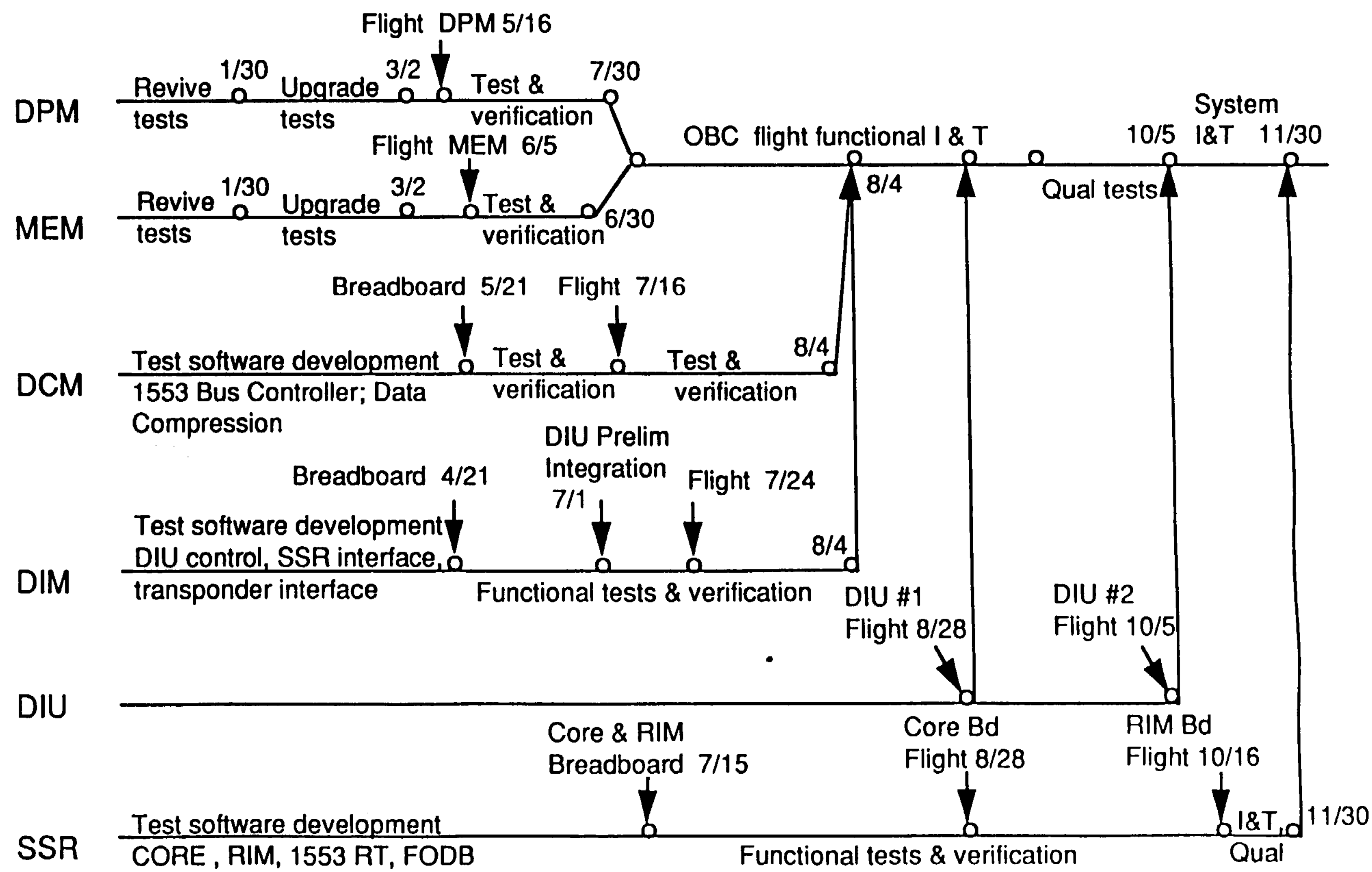
SSTI

DMS Status Summary

TRW

- Functional and interface requirements specifications for all units complete. Detailed designs and simulations in progress and on schedule
- Flight board procurement of Data Processor, Memory and Solid State Recorder Core Board by Jan 31, 1995
- All new FPGA designs (DIM, DCM, Data I/O and Data Controller) in progress. DCM FPGA expected out by Jan 31, 1995
- Long lead parts procurement in progress except for: R3000 delay unit and FODB oscillator.
  - Approximately 60% of other parts on order
- DIU subcontract (Gulton) negotiated. Gulton on Letter Contract
- FODB subcontract (Honeywell) being negotiated. HI on Letter Contract
- Two OBC breadboards delivered. Third breadboard to be delivered by Jan 31, 1995

DMS Integration Plan



SPACECRAFT BUS
TT&C

D. Schall

SSTI

TT&C SUBSYSTEM REQUIREMENTS

TRW

- RECEIVE UPLINK COMMANDS FROM EITHER NASA GSTDN/DSN OR TRW CHANTILLY GROUND STATIONS
  - NASA GSTDN/DSN For Contingency Ops
  - Chantilly GS For Nominal Ops
  - NASA Compatible Format (e.g. 48 bit command, 240/221 FT/FR, 2 kbps, 16 kHz subcarrier, S-band channel)
  - 10-6 BER Link With 3 dB Margin
  -
- TRANSMIT DOWNLINK SOH TELEMETRY AND PAYLOAD DATA TO GROUND STATIONS
  - SOH TLM Only To NASA GSTDN/DSN During Contingency Ops
  - Both TLM And DATA To Chantilly (& Fairbanks, Ak)
  - 10-6 BER For All DATA; Except 10-9 For Compressed HSI DATA With 3 dB Margin
  -
- TRACKING/RANGING SUFFICIENT FOR EPHEMERIS DETERMINATION AND PROPAGATION
  - Compatible With NASA Standard Tone and PRN Systems

SSTI

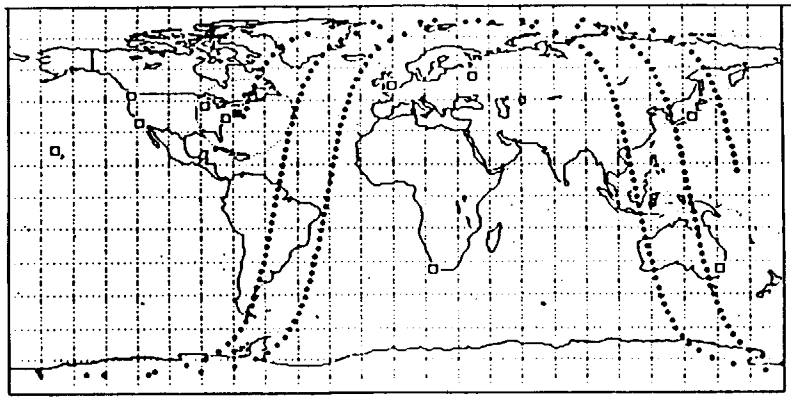
TT&C SUBSYSTEM
ADDITIONAL REQUIREMENTS

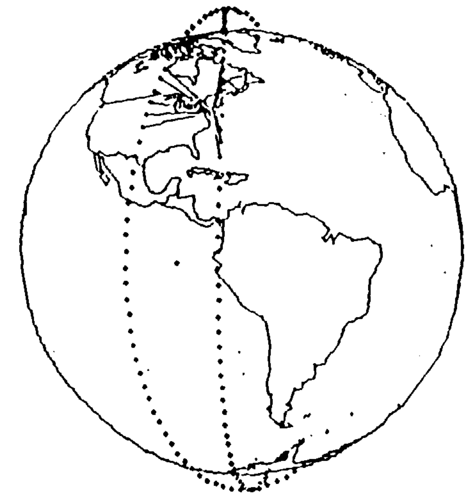
TRW

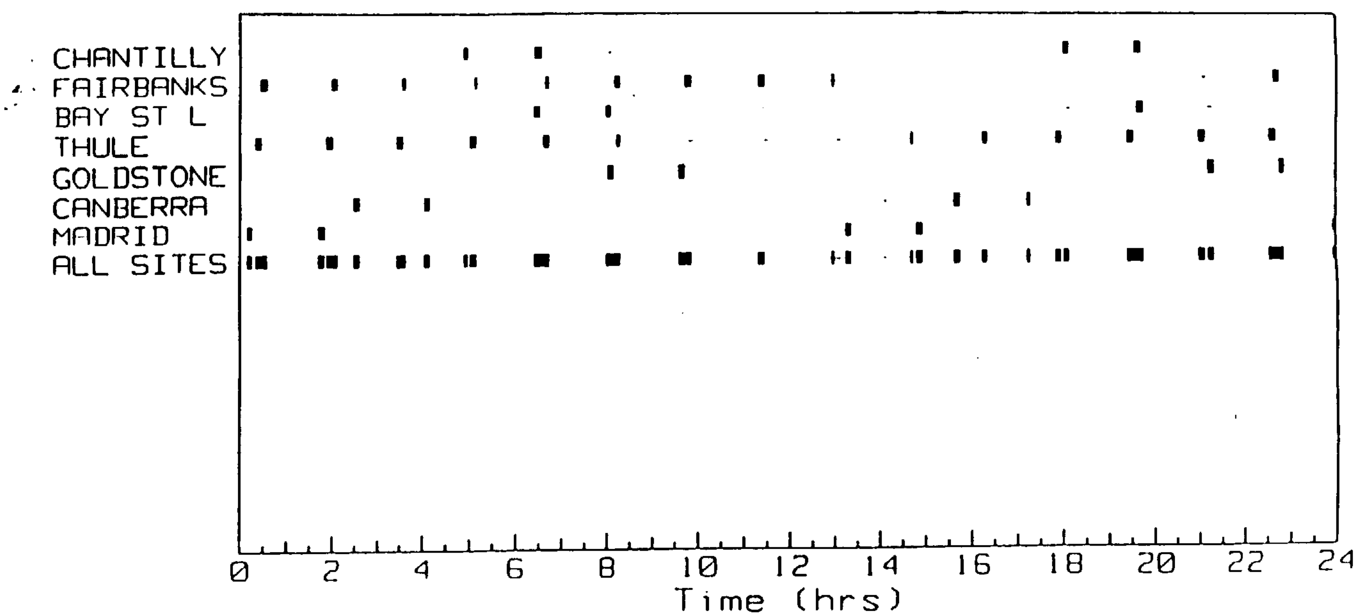
- GND STAs TO HAVE MIN 5 DEG EL ANGLE
- 1-2 CONTACTS WITH CHANTILLY TWICE A DAY; 10-12 CONTACTS WITH FAIRBANKS PER DAY
- MAINTAIN GND STA COMM WITH S/C OFF-NADIR POINTING 22 DEG IN ROLL OR 45 DEG IN PITCH
- PROVIDE CMD & TLM CAPABILITIES DURING ANOMALOUS/CONTINGENCY OPS

- BUILD ON TOMS DESIGN
- 2 GBITS OF DATA PER DAY REQUIRES 2.048 MBPS MIN. DOWNLINK DATA RATE (28 Minutes Contact Time Per Day)
- LINK CLOSURE & QUALITY REQUIREMENTS(10-6 & 10-9 BER):
  - Transmit RF Power = 5.0 W
  - Antenna Gain = 4.0 dBiC (at max slant range)
- NOMINAL, CONTINGENCY & OFF-NADIR OPS REQUIRE USEABLE ANTENNA HALF CONE BEAMWIDTH OF 115 DEG

SSTI FLIGHT OVERVIEW







SSTI

TT&C SUBSYSTEM
OPERATIONS CONCEPT

TRW

- DURING CONTINGENCY OPS, NASA GSTDN/DSN GND STAs WILL OPERATE THE S/C (Totally NASA Standard)
  - 2 kbps Commanding On 16 kHz Subcarrier
  - 8.0 kbps Convolutionally Coded SOH TLM On 1.024 MHZ Subcarrier
  - Ranging Tones /PRN Data Over Commandable Coherent/Noncoherent Turnaround Channel
  -
- DURING LEO, CHECKOUT, AND NOMINAL OPS, TRW WILL OPERATE S/C FROM CHANTILLY, VA. GROUND STATION
  - 2 kbps Commanding On 16 kHz Subcarrier
  - 2.048 Mbps Science DATA Plus Embedded SOH TLM
  - Tracking
    - By Onboard TRW GPS Receiver
    - By Two Way Coherent Doppler Measurement
    - By One Way Doppler Measurement
  - DATA Will Also Be Downlinked To Fairbanks (Potential Cmd Site)
  - After The First Year On Orbit, NASA Will Control The S/C

SSTI

TT&C SUBSYSTEM
SUMMARY DESCRIPTION

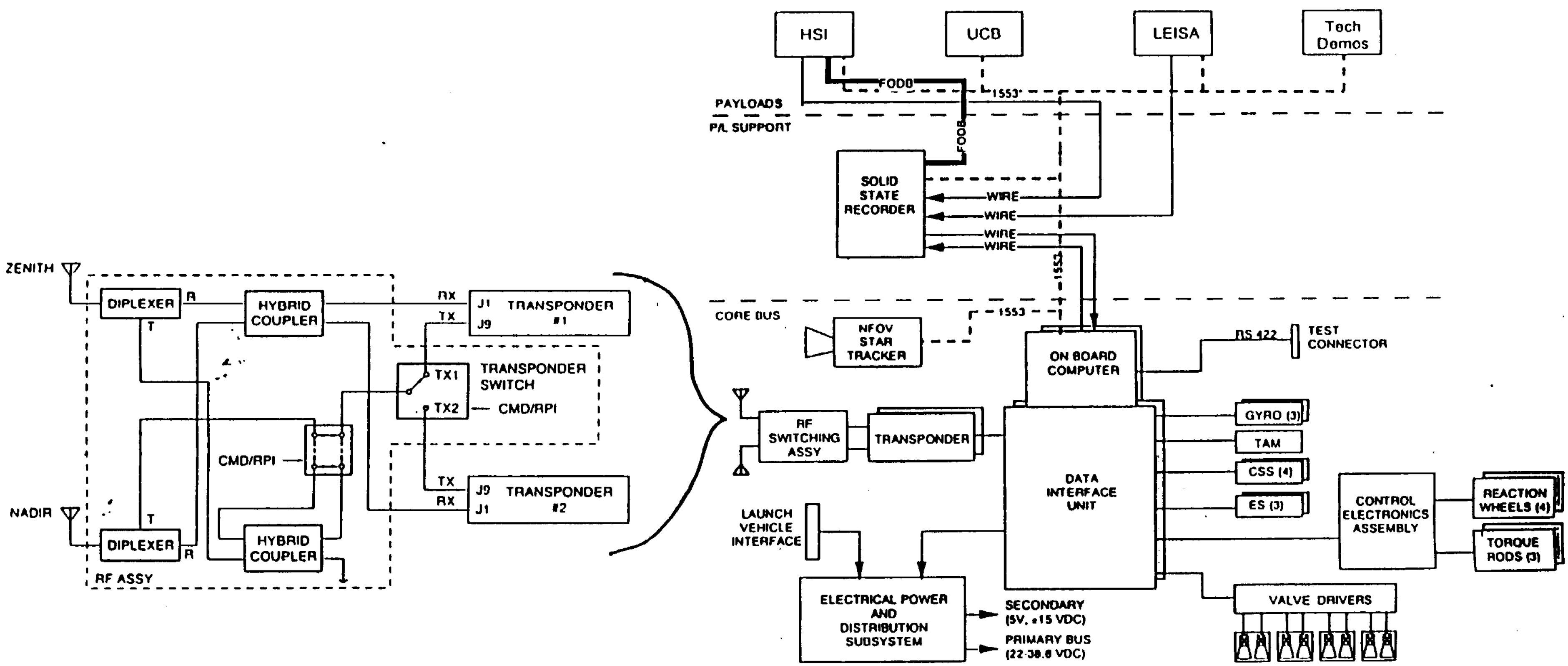
- TT&C SUBSYSTEM CONSISTS OF:
  - Transponders (Interfaces with DMS and RF Assembly)
  - RF Assembly (Interfaces with transponders and antennas)
  - Antennas (Provide RF interface with ground stations)

- SUBSYSTEM BUILDS ON TOMS DESIGN AND STEP HERITAGE
  - NASA GSTDN/DSN Compatible
  - On-orbit Performance (M0 & M2)
  - Incorporates Hardware With Flight Heritage And Redundancy To Minimize Risk

SSTI

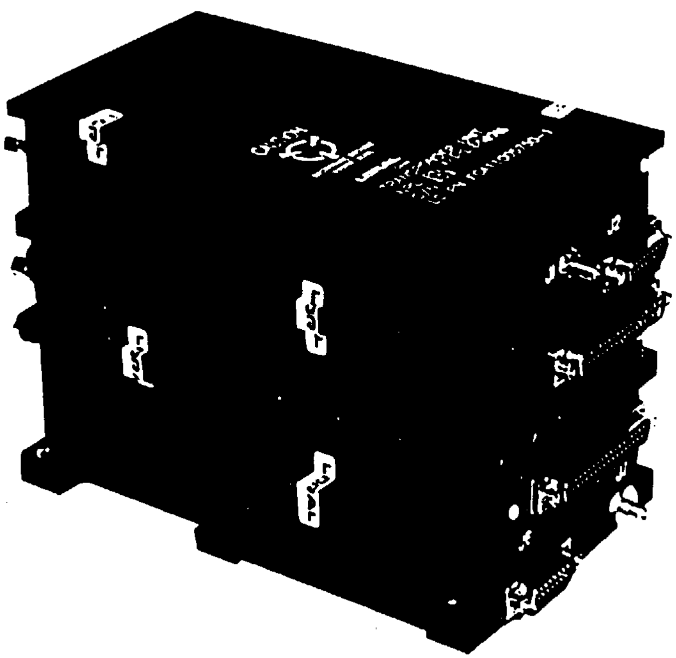
TT&C SUBSYSTEM BLOCK DIAGRAM

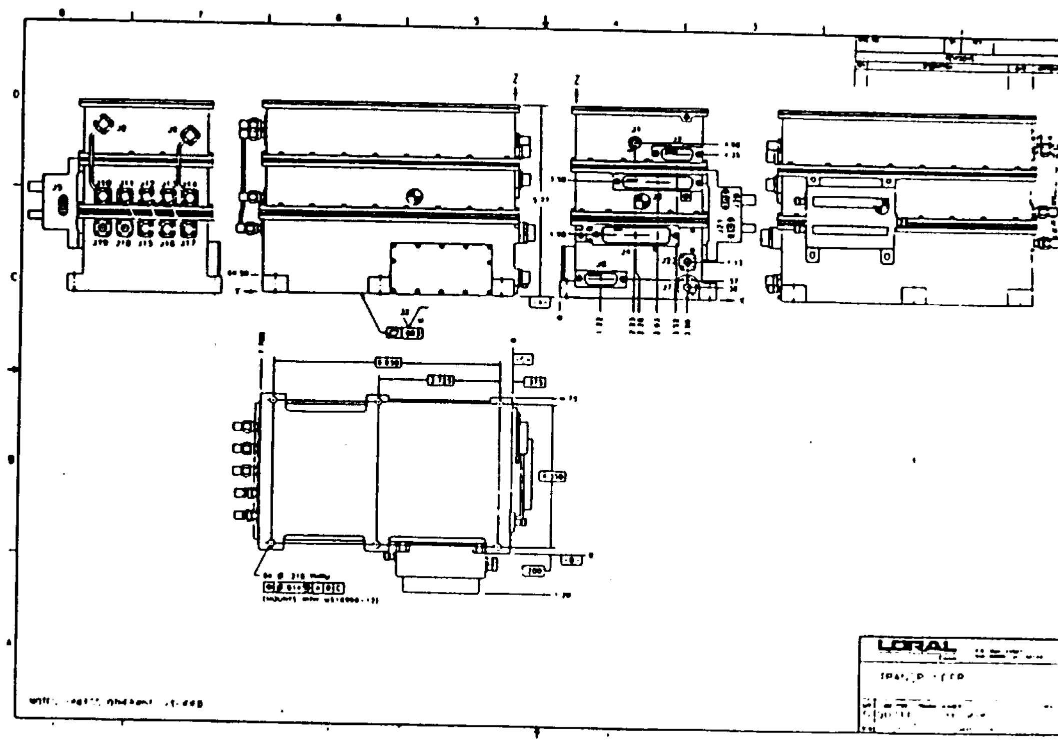
TRW



TT&C SUBSYSTEM
RF TRANSPONDER

- LORAL CONIC TERRACOM CXS-600B
  - NASA Standard STDN/DSN Compatible
  - Flight Proven/TOMS & DSPSEHeritage





SSTI

TT&C SUBSYSTEM
TRANSPONDER CHARACTERISTICS

TRW

- VENDOR: LORAL CONIC TERRACOM, SAN DIEGO, CA.
- HERITAGE: TOMS, STEP, DSPSE (CLEMENTINE), OTHERS; NO FAILURES ON ORBIT!

- RECEIVER/DEMODULATOR:
  - Frequency: 2095.172 MHz
  - Coherency Ratio: 240/221 FT/FR
  - Type: Double Conversion SuperHet PSK
  - Commands: 2 kbps on 16 kHz Subcarrier
  - El. Power: 3.8 W (100% duty cycle)

TRANSMITTER/MODULATOR:
  - Frequency: 2275.300 MHz
  - RF Power: 5.0 W
  - Mode 1: 8.000 kbps SOH TLM On 1.024 MHz Subcarrier Plus NASA Ranging; Mode 2: 2.048 Mbps BPSK On Carrier
  - El. Power: 39.0 W (10% duty cycle)

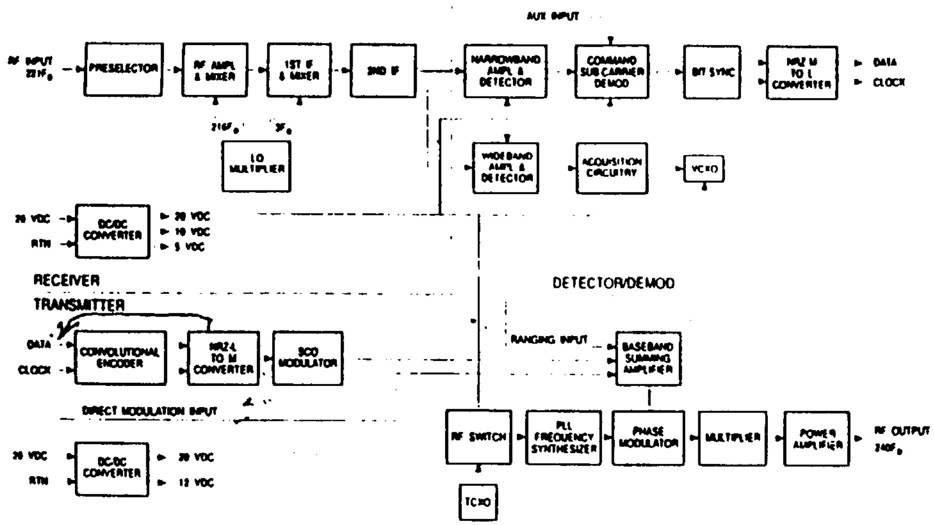
TRANSPONDER CHAR.(Concluded)

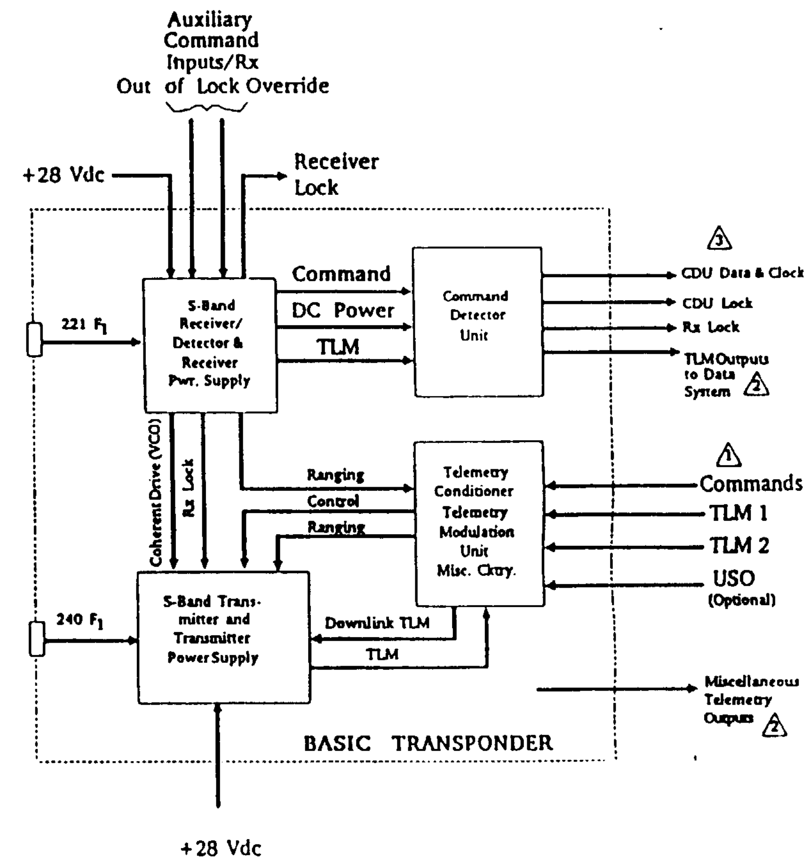
- ADDITIONAL FEATURES:
  - NRZ-L To NRZ-M Data Format Converter
  - 1.024 MHz Subcarrier Oscillator
  - Convolutional Encoder (NASA Std r=1/2, k=7 Viterbi)
  - UltraStable Oscillator(5 parts in 10x10 for one way doppler ranging; 1.14 Hz accuracy out of approx. 25000 Hz max. Doppler)

- PHYSICAL
  - Weight: < 9.0 #
  - Temperature: 0 To + 50 Degrees C For Acceptance Test
  - Reliability: 0.920 At End Of 3 Years; 0.840 At End Of 5 Years
  - Radiation Hardness: > 35 kRads(Si); 10 kRads(Si) Required

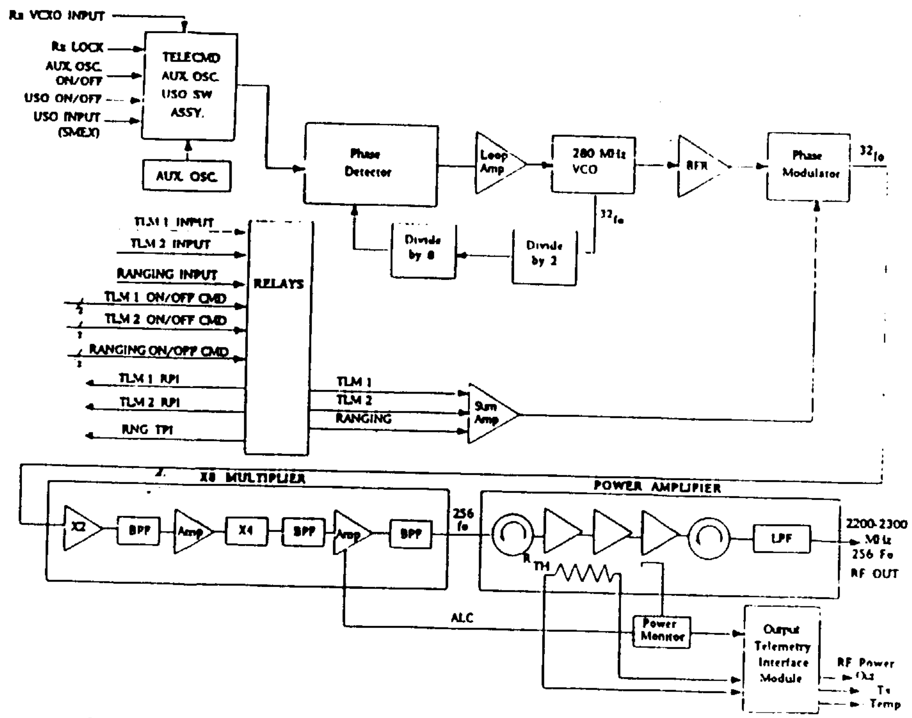
- STATUS
  - LORAL Under Letter Contract
  - Final EQ Spec Due 15 Jan 95
  - Delivery 15 Dec 95

TT&C SUBSYSTEM
TRANSPONDER BLOCK DIAGRAM





1. MULTIPLE REDUNDANT COMMANDS
2. SELECTED TELEMETRY OUTPUTS REDUNDANT
3. CDU DATA AND CLOCK



High Frequency OCXOs - continued

Miniature PC Board Mount OCXOs (32 kHz-50 MHz)

Features:
- Superior aging
- Ultra-high temperature stability
- Very fast warm-up

		CO-734 SERIES (AT Cut Crystal)	CO-7385 SERIES (SC/IT Cut Crystal)
FREQUENCY		5 MHz and 10 MHz standard. Other frequencies available in [illegible] MHz range with sine output and in 32 kHz-17 MHz range with logic output. See Series CO-724 for 50-150 MHz and CO-725 for 50-200 MHz	
STABILITY	Temperature		
(Temp Range A)	+15°C to +35°C	CO-73□A30: ±3 x 10[illegible] CO-73□A50: ±5 x 10[illegible] CO-73□A20: ±2 x 10[illegible]	[illegible]: ±1 x 10[illegible] [illegible]: ±5 x 10[illegible] [illegible]: ±3 x 10[illegible]
(Temp Range B)	0°C to +50°C	CO-73□B30: ±3 x 10[illegible] CO-73□B10: ±1 x 10[illegible] CO-73□B50: ±5 x 10[illegible]	[illegible]: ±1 x 10[illegible] [illegible]: ±1 x 10[illegible] [illegible]: ±5 x 10[illegible] ✓
(Temp Range D)	-20°C to +70°C	CO-73□D17: ±1 x 10[illegible] CO-73□D30: ±3 x 10[illegible] CO-73□D10: ±1 x 10[illegible]	[illegible]: ±1 x 10[illegible] [illegible]: ±3 x 10[illegible] [illegible]: ±2 x 10[illegible]
(Temp Range E)	-40°C to +75°C	CO-73□E17: ±2 x 10[illegible] CO-73□E50: ±5 x 10[illegible] CO-73□E20: ±2 x 10[illegible]	[illegible]: ±5 x 10[illegible] [illegible]: ±1 x 10[illegible] [illegible]: ±4 x 10[illegible]
	Aging Rate	6. 1 x 10[illegible]/day (2 x 10[illegible]/year) 7. 1 x 10[illegible]/day (3 x 10[illegible]/year)	5 x 10[illegible]/day (1 x 10[illegible]/year) 4 to 32 MHz only [illegible] x 10[illegible]/year optional at some frequencies 2 x 10[illegible]/year at 5 MHz optional
	Supply	5 x 10[illegible] per percent	1 x 10[illegible] [illegible]
	Short Term (Allan Variance)	5 x 10[illegible] per second	5 x 10[illegible] per second
	Warm-up (Restabilization) (frequency relative to that two hours after turn on following 24 hours off time at +25°C)	1 x 10[illegible] 5 minutes 1 x 10[illegible] 7 minutes 3 x 10[illegible] 10 minutes 1 x 10[illegible] 20 minutes	1 x 10[illegible] 2 minutes 1 x 10[illegible] 2.5 minutes 2 x 10[illegible] 3 minutes 1 x 10[illegible] 4 minutes ✓
		(If maximum operating temperature exceeds 70°C, warm-up time will increase)	
OUTPUT / SUPPLY	Output	Output: Standard: +0.5 Vrms into 50 Ω (-7 dBm); Option "R": +1.0 Vrms into 50 Ω (+13 dBm); Option "F": **HCMOS/TTL	Supply (±5%): +15 Vdc*; +15 Vdc*; * +15 Vdc and -5 Vdc > 400 mA
		* Any voltage in +12-24 Vdc range optional. Supply below 15 Vdc results in reduced sinewave output level ** Drives 3 TTL loads, 10 LSTTL loads or HCMOS, output is from HCMOS gate	
	Harmonics (Sinewave Output)	20 dB below desired output. If internal multiplication is used, generally above 12 MHz, subharmonics are also -20 dBc. Harmonic and subharmonic attenuation can be improved on special order	
	Input Power	6 watts at turn-on, less than 2 watts stabilized at +25°C. Higher power required for temperature beyond -20 to +70°C and lower power needed for 5 to +50°C	
PHASE NOISE	(Sinewave Output 4-12 MHz)	Offset / Phase Noise: 10 Hz -100 dBc/Hz 100 Hz -135 dBc/Hz 1 kHz -145 dBc/Hz 10 kHz -150 dBc/Hz 50 kHz -150 dBc/Hz	[illegible]
FREQUENCY ADJUST	Tuning via external potentiometer	10 ppm minimum range for 0 to 5V control	[illegible]
MECHANICAL PACKAGE		1.5" x 1.25" x 0.88" (38 x 32 x 22 mm). Pins for PC board mounting: see page 52 Option "C": European CO-08 package: see page 50	
ENVIRONMENTAL		See general environmental specifications on page 78	
HOW TO ORDER		See page 52	

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TT&C SUBSYSTEM
RF ASSEMBLY

- MODIFIED TOMS DESIGN
  - Provides Commandable NADIR OR NADIR and ZENITH Antenna Pattern Combining For Transmit
  - Provides NADIR AND ZENITH Antenna Pattern Combining For Receive
  - Provides Commandable Selection of Transponder Transmitters
  - Receivers ON Continuously

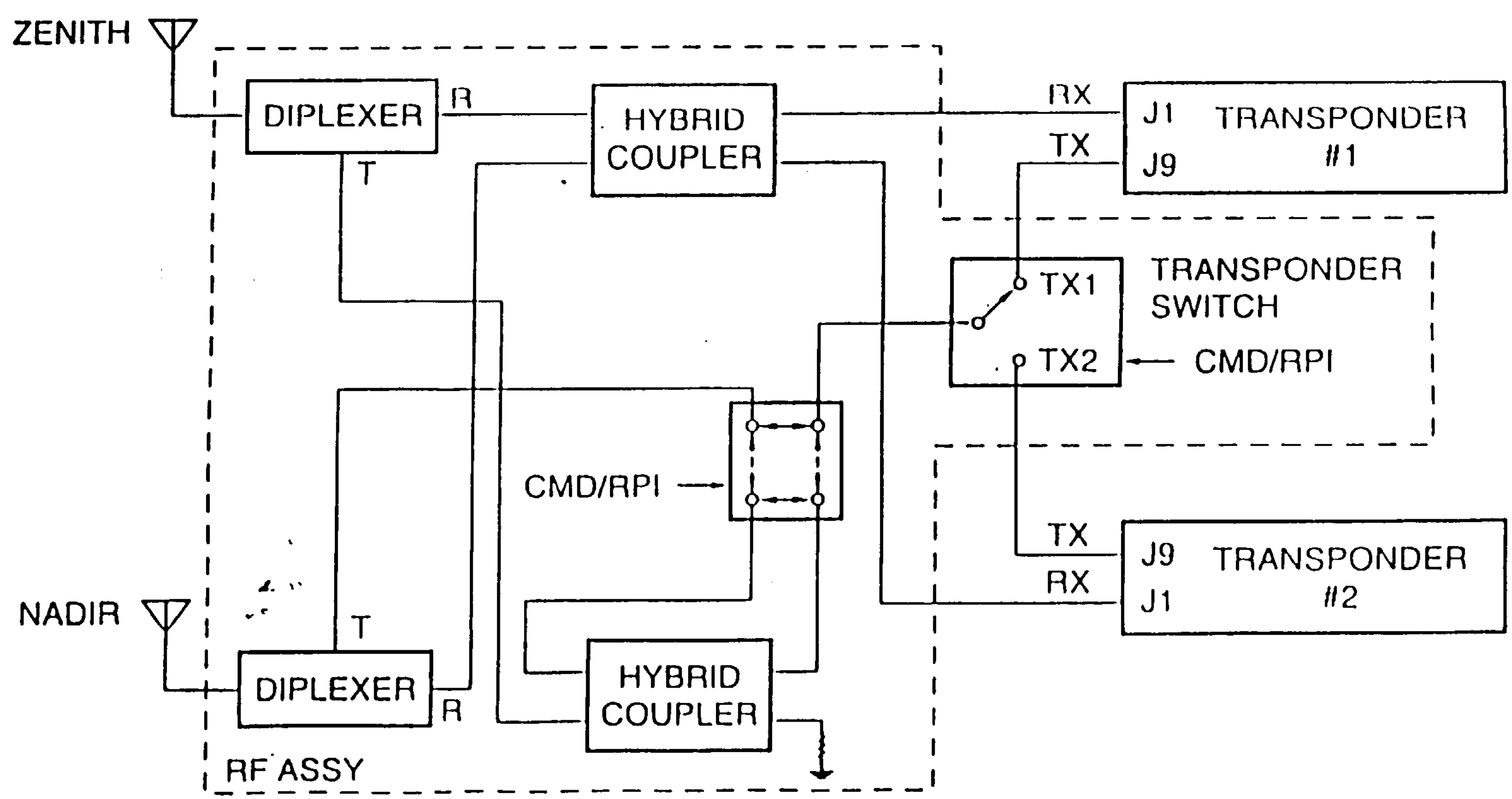
- STATUS
  - Subcontract Award To Be Made NLT 15 Jan 95
  - Size, Weight, Layout Are TBD (Footprint Provided)

SSTI

TT&C SUBSYSTEM
RF ASSEMBLY BLOCK DIAGRAM

TRW

- **Combines Antennas For Receiving**
- **Upon Command, Selects Transponder Transmitter**
- **Upon Command, Selects Nadir <u>OR</u> Nadir and Zenith Antenna(s) For Transmitting**

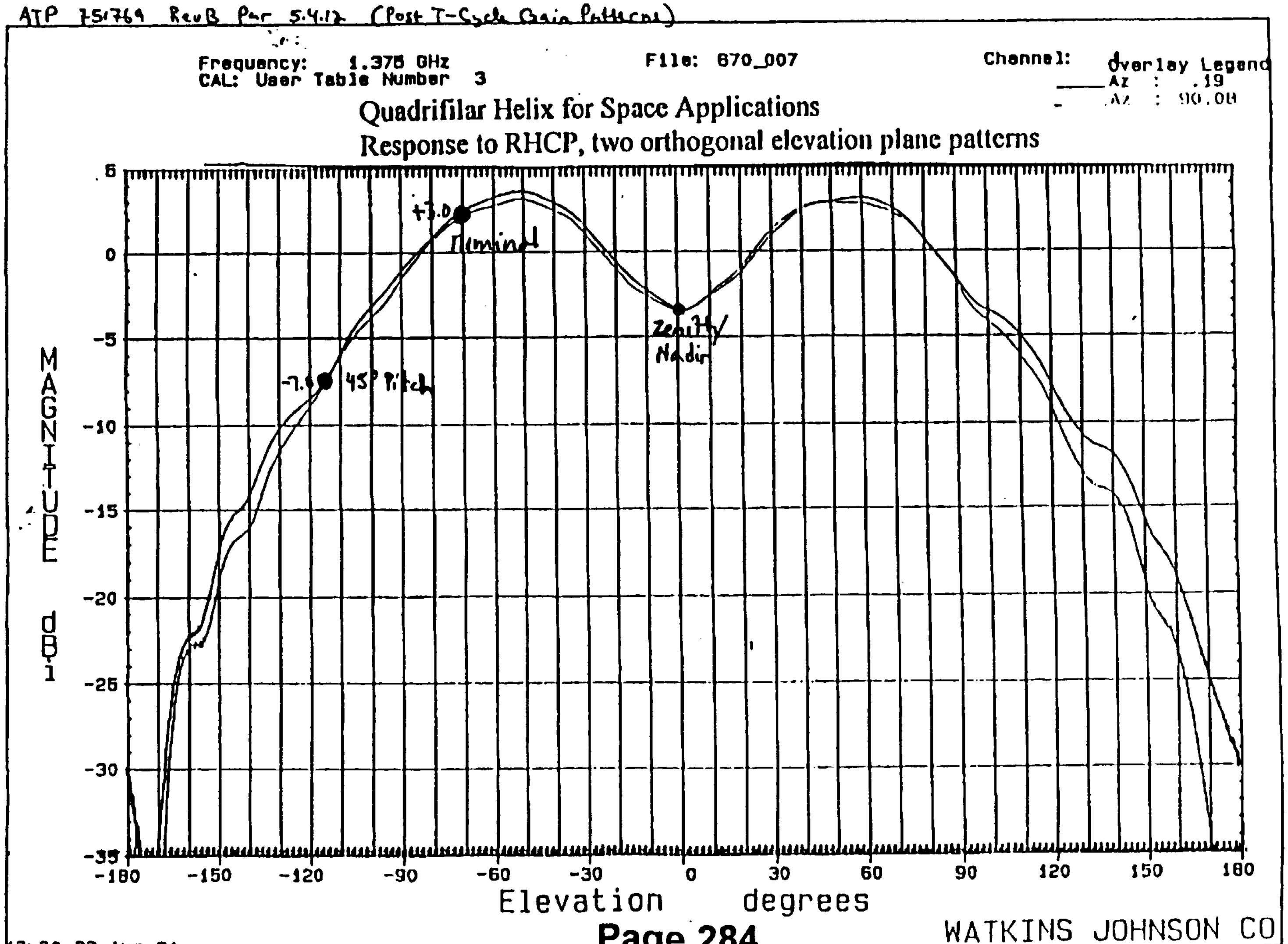


TT&C SUBSYSTEM
S-BAND ANTENNAS

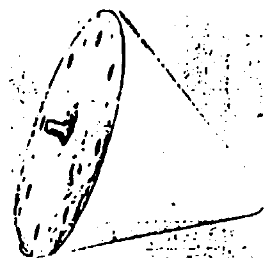
- QUADRIFILAR HELIX PROVIDES DESIRED GAIN AND PATTERN
- WATKINS JOHNSON HAS BUILT AND SPACE FLOWN THIS ANTENNA AT 1.375 GHz (L-Band)
- WJ WILL SCALE THIS ANTENNA FOR SSTI S-BAND OPERATION
- SIMILAR TO STEP ANTENNAS (Different Vendors); TWO STEP S/C CURRENTLY OPERATING SUCCESSFULLY ON ORBIT USING THIS TYPE OF ANTENNA
- STATUS:
  - WJ Under Contract
  - Delivery In April 95

- ## DESIRE MAXIMUM GAIN AT EDGE OF BEAM

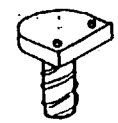
ATP 751769 RevB Par 5.4.12 (Post T-Cycle Gain Patterns)

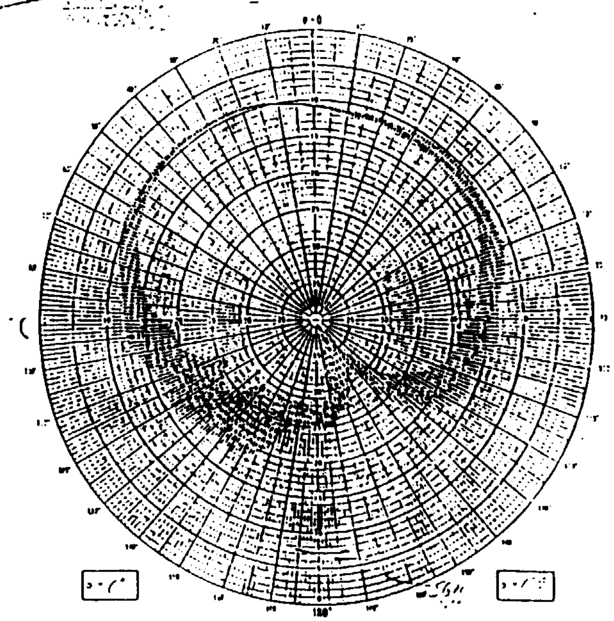


S-BAND ANTENNA PATTERNS

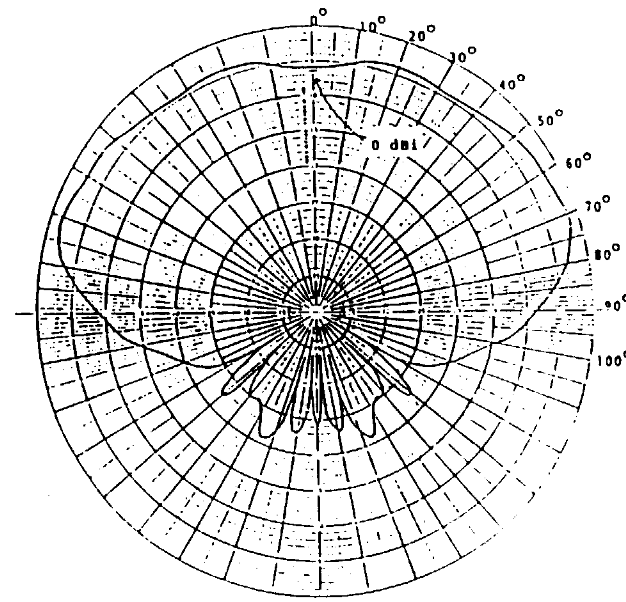


WJ-48915





TOMS



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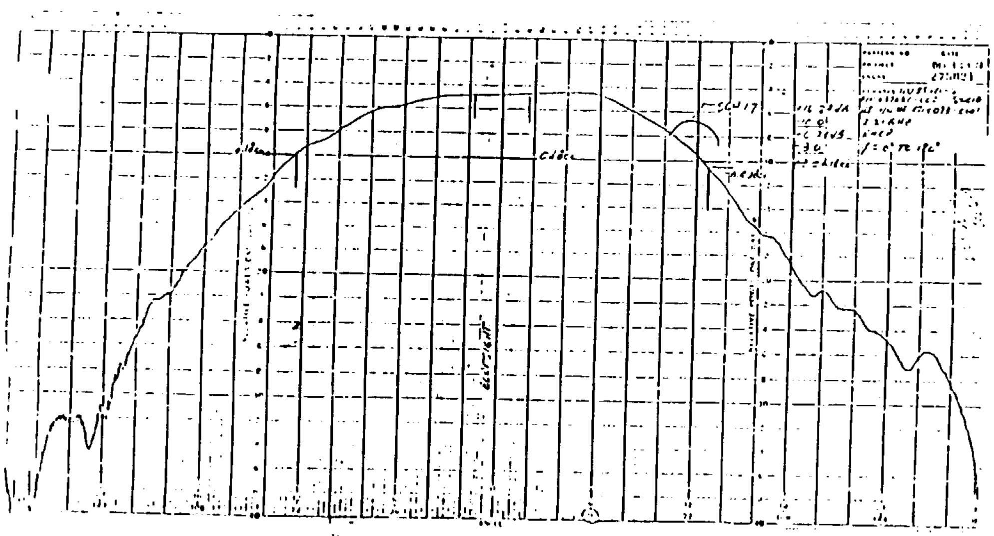
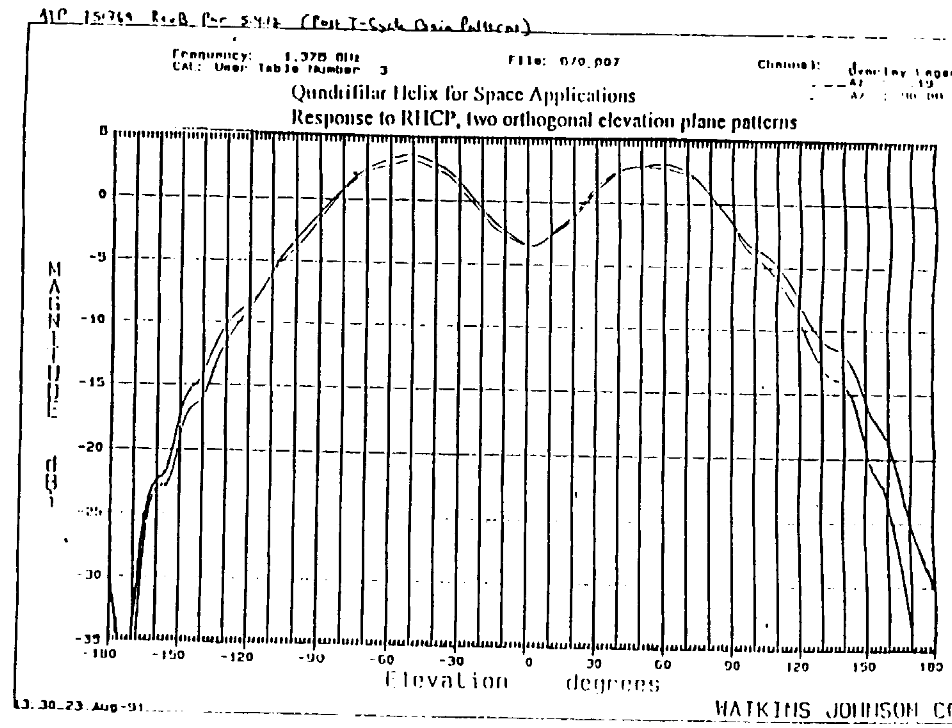
S-BAND ANTENNA PATTERNS





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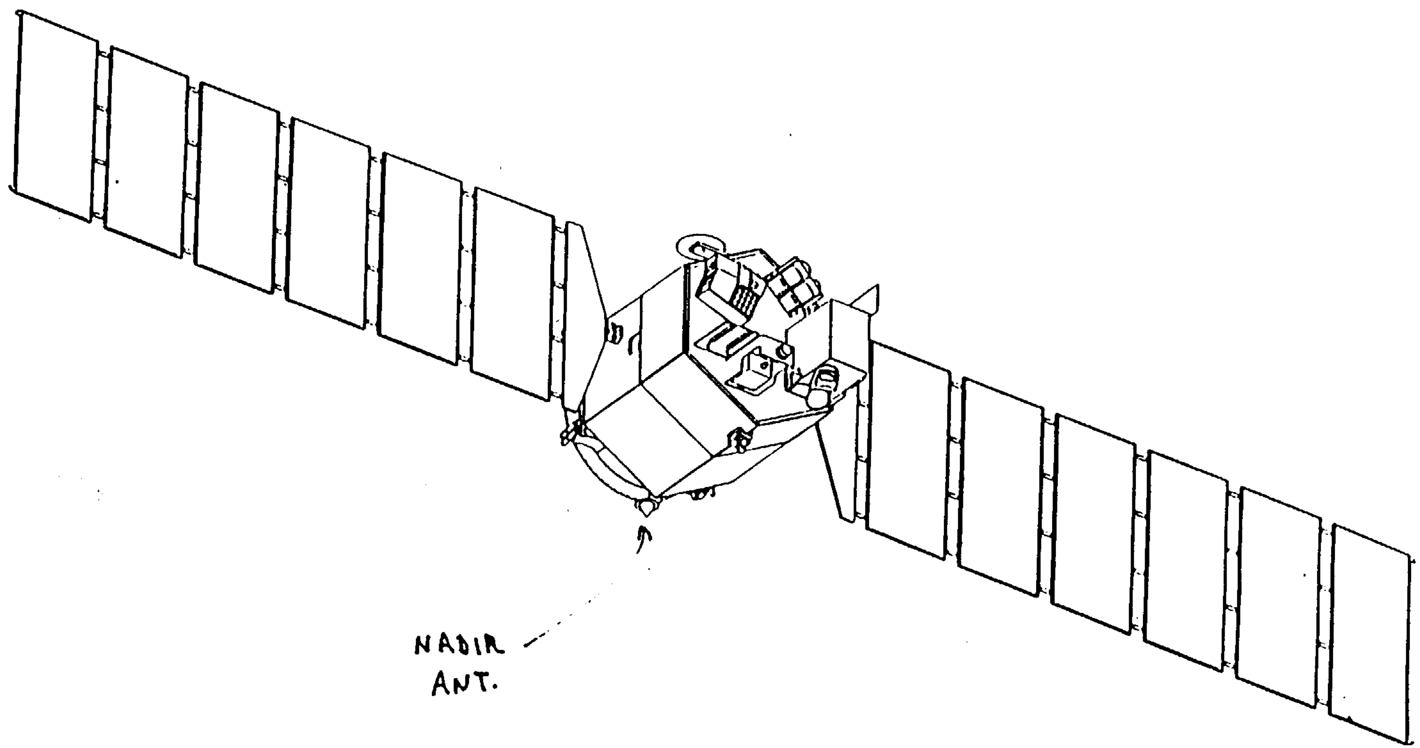
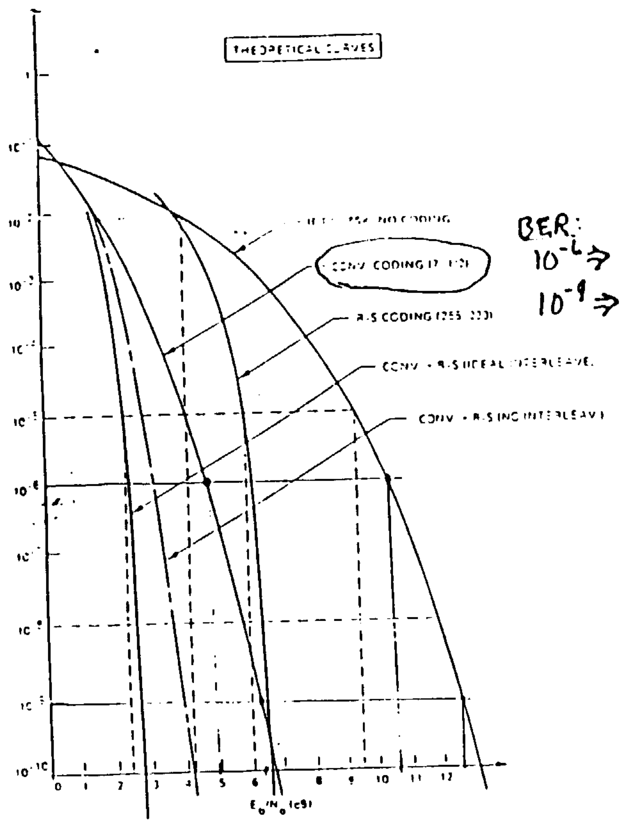
S-BAND ANTENNA POSITIONING

TRW





BER:
$10^{-6} \Rightarrow 5.0$ dB
$10^{-9} \Rightarrow 6.5$ dB

FIGURE A-2. RELATIVE PERFORMANCE OF CONCATENATED CODING WITH R-S OUTER CODE (R-S IDEAL INTERLEAVING AND NO-INTERLEAVING COMPARISON)

Site Designation:	Chantilly
Rain Region:	D1
Station Latitude, deg:	39.00
Antenna Altitude, km:	0.00
Frequency, GHz:	2.1

ATTENUATION (dB) VS. ELEVATION ANGLE (deg)

Av% / Elev	99.999	99.998	99.995	99.99	99.98	99.95	99.9	99.8	99.5	99.0	98.0	95.0
0.0	4.24	3.54	2.79	2.33	1.95	1.47	1.14	0.85	0.59	0.44	0.33	0.22
5.0	0.36	0.45	0.34	0.27	0.20	0.11	0.10	0.07	0.04	0.03	0.02	0.00
10.0	0.20	0.17	0.14	0.11	0.08	0.06	0.04	0.03	0.02	0.01	0.01	0.00
15.0	0.19	0.16	0.12	0.09	0.07	0.05	0.03	0.02	0.01	0.01	0.01	0.00
20.0	0.17	0.14	0.11	0.08	0.06	0.04	0.03	0.02	0.01	0.01	0.00	0.00
25.0	0.14	0.11	0.10	0.07	0.05	0.03	0.02	0.01	0.01	0.01	0.00	0.00
30.0	0.13	0.12	0.09	0.06	0.04	0.03	0.02	0.01	0.01	0.00	0.00	0.00
35.0	0.14	0.11	0.08	0.06	0.04	0.02	0.02	0.01	0.01	0.00	0.00	0.00
40.0	0.13	0.10	0.07	0.05	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00
45.0	0.12	0.10	0.07	0.05	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00
50.0	0.12	0.09	0.07	0.05	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00
55.0	0.12	0.09	0.06	0.04	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00
60.0	0.11	0.09	0.06	0.04	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00
65.0	0.11	0.09	0.06	0.04	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00
70.0	0.11	0.08	0.06	0.04	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00
75.0	0.11	0.08	0.05	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
80.0	0.11	0.08	0.05	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
85.0	0.11	0.08	0.05	0.04	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
90.0	0.11	0.08	0.05	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00

POINT RAIN RATE (mm/hr)

Percent Availability [100*(1-exceedance)]

Rain Region	99.999	99.998	99.995	99.99	99.98	99.95	99.9	99.8	99.5	99.0	98.0	95.0
A	28.5	21.0	13.5	10.0	7.0	4.0	2.5	1.5	0.7	0.4	0.1	0.0
B1	45.0	34.0	22.0	15.5	11.0	6.4	4.2	2.8	1.5	1.0	0.5	0.2
B	57.5	44.0	28.5	19.5	13.5	8.0	5.2	3.4	1.9	1.3	0.7	0.3
B2	70.0	54.0	35.0	23.5	16.0	9.5	6.1	4.0	2.3	1.5	0.8	0.3
C	78.0	62.0	41.0	28.0	18.0	11.0	7.2	4.8	2.7	1.8	1.1	0.5
→ D1	90.0	72.0	50.0	35.5	24.0	14.5	9.8	6.4	3.6	2.2	1.2	0.0
D2	108.0	89.0	64.5	49.0	35.0	22.0	14.5	9.5	5.2	3.0	1.5	0.0
D3	126.0	106.0	80.5	63.0	48.0	32.0	22.0	14.5	7.8	4.7	1.9	0.0
E	165.0	144.0	118.0	98.0	78.0	52.0	35.0	21.0	10.6	6.0	2.9	0.5
F	66.0	51.0	34.0	23.0	15.0	8.3	5.2	3.1	1.4	0.7	0.2	0.0
G	185.0	157.0	120.5	94.0	72.0	47.0	32.0	21.8	12.2	8.0	5.0	1.8
H	253.0	220.5	178.0	147.0	119.0	85.5	64.0	43.5	22.5	12.0	5.2	1.2

TT&C SUBSYSTEM
DOWNLINK BUDGETS-NOMINAL OPNS

PARAMETER	VALUE	BASIS
Frequency	2275.3 MHz	NASA Assigned
Spacecraft Altitude	523 km	
Elevation Angle	5 Degrees	GS Elevation Angle (min.)
SLANT RANGE	2137 km	
SC Transmitter Summary		
Transmit Power	36.99 dBm	LORAL CXS-600B 5.0 W
Line Loss	1.5 dB	TRW
Antenna Gain	3 dB	At 70 Deg off Boresight
Pointing Loss	0 dB	
EIRP	38.49 dBm	
Axial Ratio	5 dB	Estimate
Path Loss Summary		
Free Space	166.2 dB	
Atmosphere	0.3 dB	
Rain	0 dB	
TOTAL LOSS	166.5 dB	
GS Antenna Summary		
Pointing Loss	0.3 dB	
Axial Ratio	1.5 dB	EMP Spec
Polarization Loss	0.4 dB	45 Deg Misalignment
System G/T	11.5 dB/K	5 Deg Elevation/23 C Ambient
RECEIVED S/No	81.39 dB	
GS Receiver Summary		
IF Bandwidth	70 dB Hz	10 MHz IF Filter BW for 4 096 Msps
RECEIVED S/N	11.39 dB	
S/N Req'd for Acquisition	0 dB	Microdyne Spec/Test Results
SYSTEM MARGIN	11.39 dB	
Data Rate	66 dB Hz	4.096 Msps (conv coded)
Modulation Loss	0 dB	20 dB Carrier Supression
Demod Loss	1.5 dB	Microdyne Test Results
Eb/No	13.89 dB	
Eb/No Required	6.2 dB	TRW
SYSTEM MARGIN	7.69 dB	

PARAMETER	VALUE	BASIS
Frequency	2275.3 MHz	NASA Assigned
Spacecraft Altitude	523 km	
Elevation Angle	90 Degrees	GS Elevation Angle (Zenith)
SLANT RANGE	523 km	
SC Transmitter Summary		
Transmit Power	36.99 dBm	LORAL CXS-600B 5 0 W
Line Loss	1.5 dB	TRW
Antenna Gain	-3 dB	Nadir Pointing
Pointing Loss	0 dB	
EIRP	32.49 dBm	
Axial Ratio	5 dB	Estimate
Path Loss Summary		
Free Space	153.91 dB	
Atmosphere	0.3 dB	
Rain	0 dB	
TOTAL LOSS	154.21 dB	
GS Antenna Summary		
Pointing Loss	0.3 dB	
Axial Ratio	1.5 dB	EMP Spec
Polarization Loss	0.4 dB	45 Deg Misalignment
System G/T	11.7 dB/K	
RECEIVED S/No	87.88 dB	
GS Receiver Summary		
IF Bandwidth	70 dB Hz	10 MHz IF Filter BW for 4.096 Msps
RECEIVED S/N	17.88 dB	
S/N Req'd for Acquisition	0 dB	Microdyne Spec/Test Results
SYSTEM MARGIN	17.88 dB	
Data Rate	66 dB Hz	4.096 Msps (conv. coded)
Modulation Loss	0 dB	20 dB Carrier Supression
Demod Loss	1.5 dB	Microdyne Test Results
Eb/No	20.38 dB	
Eb/No Required	6.2 dB	TRW
SYSTEM MARGIN	14.18 dB	

SSTI

TT&C SUBSYSTEM
DOWNLINK BUDGETS-PARKING ORBIT

TRW

PARAMETER	VALUE	BASIS
Frequency	2275.3 MHz	NASA Assigned
Spacecraft Altitude	300 km	
Elevation Angle	5 Degrees	GS Elevation Angle (min.)
SLANT RANGE	1500 km	
SC Transmitter Summary		
Transmit Power	36 99 dBm	LORAL CXS-600B 5 0 W
Line Loss	1.5 dB	TRW
Antenna Gain	3 dB	At 70 Deg off Boresight
Pointing Loss	0 dB	
EIRP	38.49 dBm	
Axial Ratio	5 dB	Estimate
Path Loss Summary		
Free Space	163.06 dB	
Atmosphere	0.3 dB	
Rain	0 dB	
TOTAL LOSS	163.36 dB	
GS Antenna Summary		
Pointing Loss	0.3 dB	
Axial Ratio	1.5 dB	EMP Spec
Polarization Loss	0.4 dB	45 Deg Misalignment
System G/T	11.5 dB/K	5 Deg Elevation/23 C Ambient
RECEIVED S/No	84.53 dB	
GS Receiver Summary		
IF Bandwidth	70 dB Hz	10 MHz IF BW
RECEIVED S/N	14.53 dB	
S/N Req'd for Acquisition	0 dB	Microdyne Spec/Test Results
SYSTEM MARGIN	14.53 dB	
Data Rate	42.04 dB Hz	16.0 ksps conv coded
Modulation Loss	4 67 dB	1.0 radian Subcarrier MI; 0.5 Ranging MI
Demod Loss	1.5 dB	
Eb/No	36 32 dB	
Eb/No Required	6.2 dB	10-6 BER with r=1/2, k=7 conv. coding
SYSTEM MARGIN	30.12 dB	

PARAMETER	VALUE	BASIS
Frequency	2275 3 MHz	NASA Assigned
Spacecraft Altitude	300 km	
Elevation Angle	90 Degrees	GS Elevation Angle (Zenith)
SLANT RANGE	300 km	
SC Transmitter Summary		
Transmit Power	36 99 dBm	LORAL CXS-600B 5 0 W
Line Loss	1.5 dB	TRW
Antenna Gain	-3 dB	Nadir Pointing
Pointing Loss	0 dB	
EIRP	32 49 dBm	
Axial Ratio	5 dB	Estimate
Path Loss Summary		
Free Space	149.08 dB	
Atmosphere	0.3 dB	
Rain	0 dB	
TOTAL LOSS	149.38 dB	
GS Antenna Summary		
Pointing Loss	0 3 dB	
Axial Ratio	1 5 dB	EMP Spec
Polarization Loss	0 4 dB	45 Deg Misalignment
System G/T	11.5 dB/K	5 Deg Elevation/23 C Ambient
RECEIVED S/No	92 51 dB	
GS Receiver Summary		
IF Bandwidth	70 dB Hz	10 MHz IF BW
RECEIVED S/N	22.51 dB	
S/N Req'd for Acquisition	0 dB	Microdyne Spec/Test Results
SYSTEM MARGIN	22 51 dB	
Data Rate	42 04 dB Hz	16 0 ksps conv. coded
Modulation Loss	4.67 dB	1 0 radian Subcarrier MI; 0.5 Ranging MI
Demod Loss	1 5 dB	Microdyne Test Results
Eb/No	44 3 dB	
Eb/No Required	6 2 dB	10 6 BER with r=1/2, k=7 conv coding
SYSTEM MARGIN	38.1 dB	

TT&C SUBSYSTEM
DOWNLINK BUDGET-PITCH/ROLL MANEUVER

PARAMETER	VALUE	BASIS
Frequency	2275.3 MHz	NASA Assigned
Spacecraft Altitude	523 km	
Elevation Angle	5 Degrees	GS Elevation Angle (min.)
SLANT RANGE	2137 km	
SC Transmitter Summary		
Transmit Power	36 99 dBm	LORAL CXS-600B 5 0 W
Line Loss	1 5 dB	TRW
Antenna Gain	-7 dB	At 115 Deg off Boresight
Pointing Loss	0 dB	
EIRP	28.49 dBm	
Axial Ratio	5 dB	Estimate
Path Loss Summary		
Free Space	166 2 dB	
Atmosphere	0 3 dB	
Rain	0 dB	
TOTAL LOSS	166 5 dB	
GS Antenna Summary		
Pointing Loss	0 3 dB	
Axial Ratio	1 5 dB	EMP Spec
Polarization Loss	0 4 dB	45 Deg Misalignment
System G/T	11.5 dB/K	5 Deg Elevation/23 C Ambient
RECEIVED S/No	71.39 dB	
GS Receiver Summary		
IF Bandwidth	70 dB Hz	10 MHz IF Filter BW for 4.096 Msps
RECEIVED S/N	1.39 dB	
S/N Req'd for Acquisition	0 dB	Microdyne Spec/Test Results
SYSTEM MARGIN	1.39 dB	
Data Rate	66 dB Hz	4.096 Msps (conv. coded)
Modulation Loss	0 dB	20 dB Carrier Supression
Demod Loss	1.5 dB	Microdyne Test Results
Eb/No	3.89 dB	
Eb/No Required	6.2 dB	TRW
SYSTEM MARGIN	-2.31 dB	

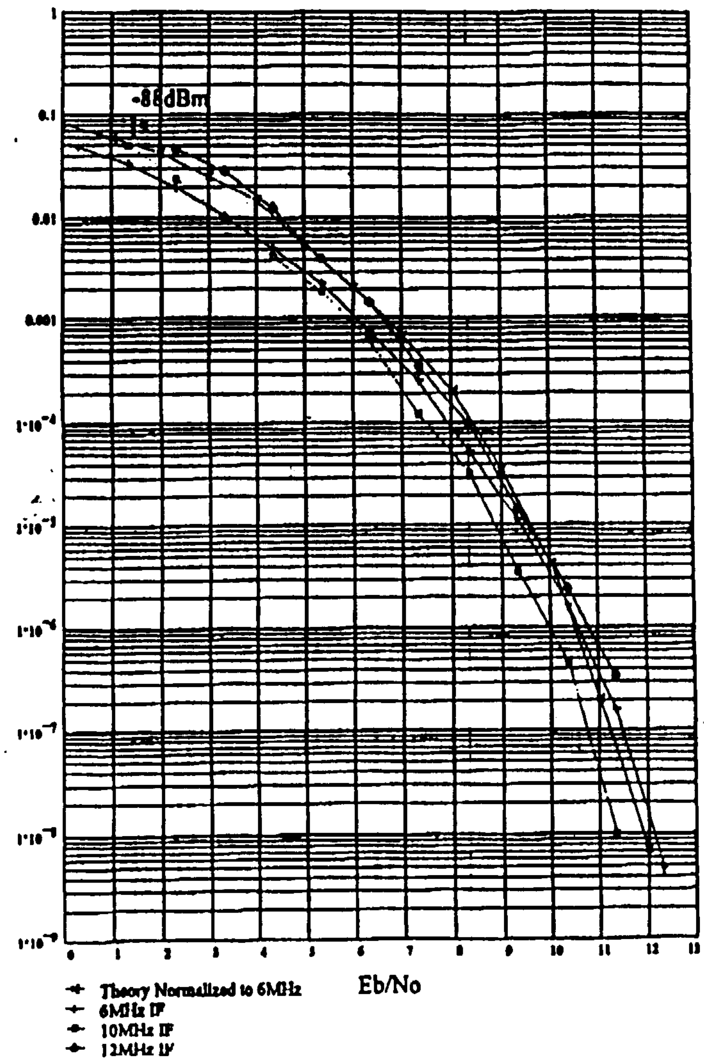
SSTI

TT&C SUBSYSTEM
GROUND STATION RECEIVER TESTS

TRW

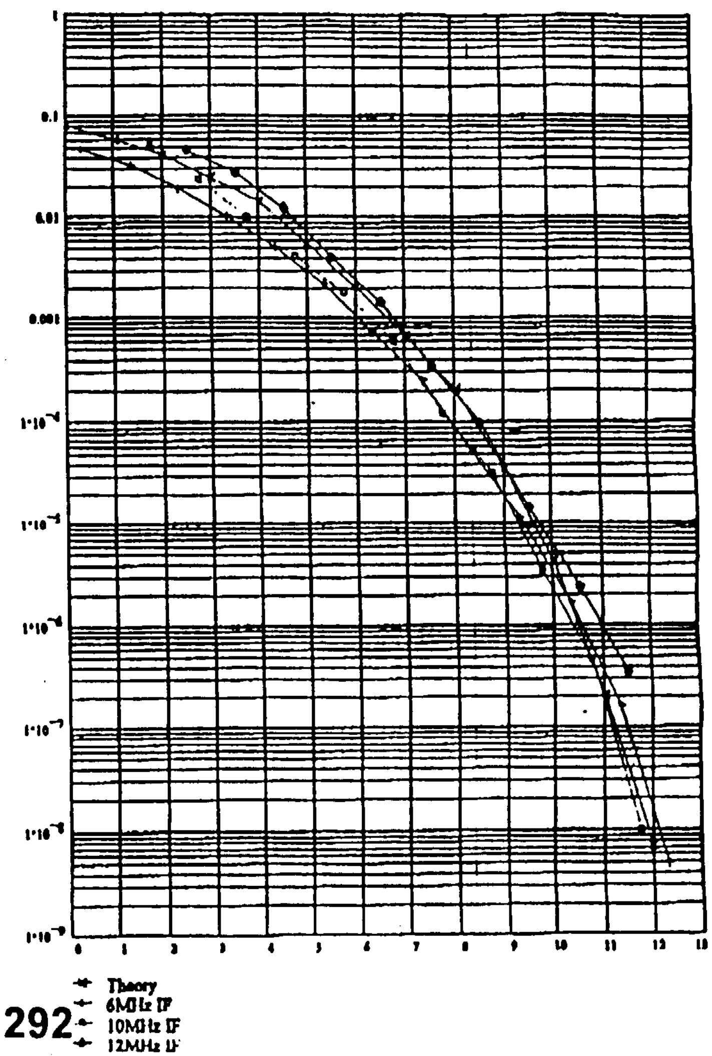
4.5MB NRZ-L, -20dB Null,
.7*BR 4pole Bessel prefilter
-88dBm = 0dB C/N in 6.1MHz IF

Figure 1
8-31-94



4.5MB NRZ-L, -20dB Null,
.7*BR 4pole Bessel prefilter
Normalized for IF/BR

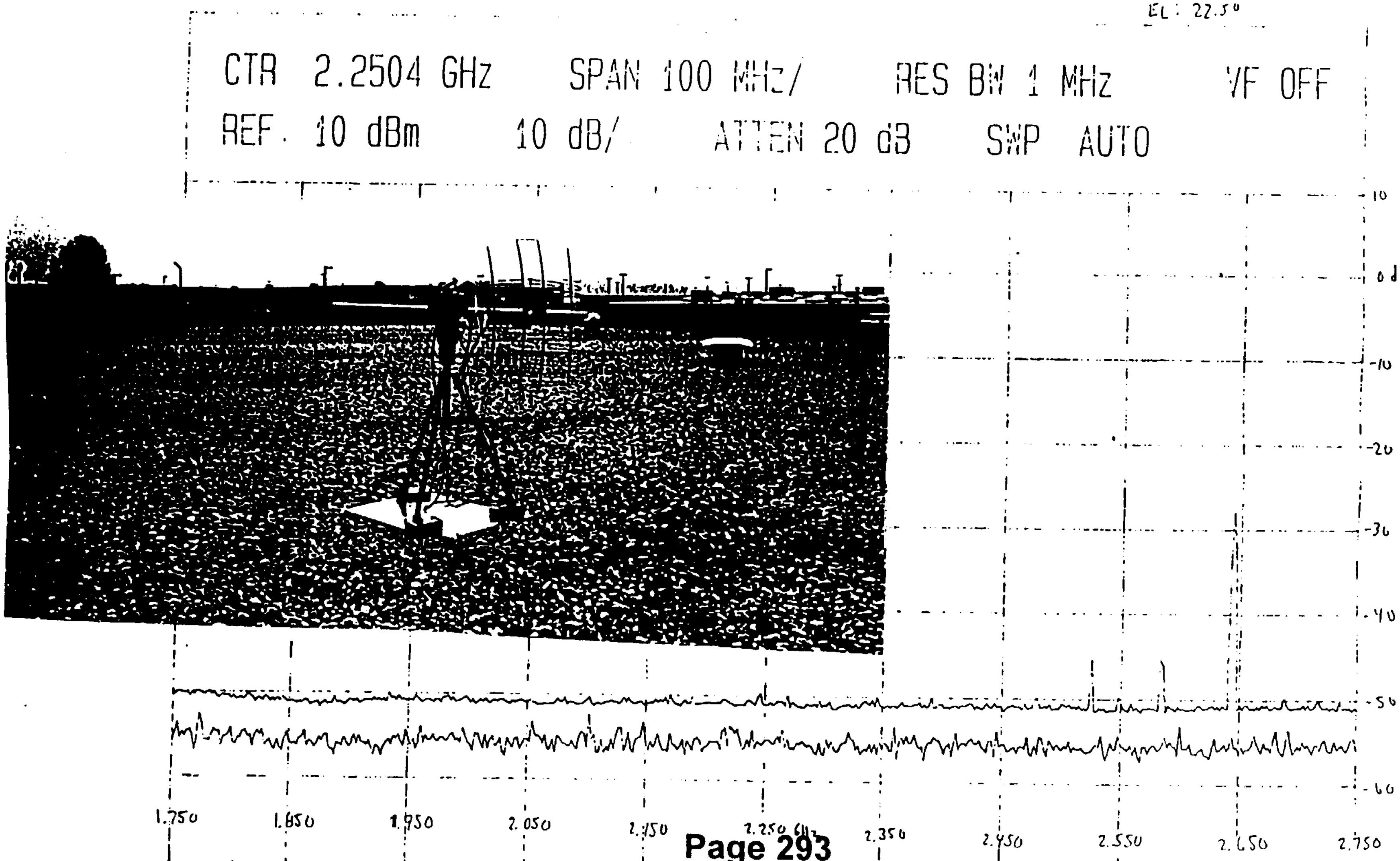
Figure 2
8-31-94



TT&C SUBSYSTEM
CHANTILLY GROUND STATION NOISE FLOOR

SSTI TRW

0835L 9/19/94 Monday
Az: South
EL: 22.5°



SSTI

TT&C SUBSYSTEM
CAPABILITIES vs REQUIREMENTS

TRW

REQUIREMENT	CAPABILITY	VERIFICATION
Compatible With DSN/GSTDN – Commanding (UGD-Format) – Telemetry – Tracking (PRN or Tones)	Met By Incorporating NASA-STD Transponder	Acceptance, IST, and Compatibility Tests
Rcv Commands At All Times	Omni Rcv Pattern	Chamber Test
– U/L Freq. 2095.172 MHz	Assigned By NASA	Acceptance Test
– 2.000 kbps	NASA Standard Rate	Compatibility Test
– 2.5 Deg/Sec Spin (max)	>2.5 Deg/Sec Spin	Analysis
Link Quality (>3dB for 5 Deg Elevation Angle Gnd Sta)		
– 10-6 BER 95% TA U/L	6.00 dB Margin	Analysis/Design
– 10-6 BER D/L (SOH TLM/ Data)	6.00 dB Margin	
– 10-6 BER D/L (Compr Data)	4.69 dB Margin	

SSTI

TT&C SUBSUSTEM
CAPABILITIES vs REQUIREMENTS

REQUIREMENT	CAPABILITY	VERIFICATION
Contact Once Per Orbit	100% RX Duty Cycle 10% TX Duty Cycle	IST & Analysis
TT&C in 300 km Parking Orbit	U/L Exceeds ---------- D/L Exceeds 30 dB	Analysis
XMT SOH TLM & Data	EIRP=38.5 dBm	IST & Analysis
– D/L Freq. 2275.300 MHz	Assigned By NASA	---
– 8.000 kbps SOH TLM + RNG	NASA Std Rate	IST
– 2.048 Mbps Data & TLM	2.048 Mbps Rate	IST
Subsystem Life of 5 Years	>5 Year Life	Reliability Anal.
Communicate in 22 Deg Roll 45 Deg Pitch	>22 Deg Roll >45 Deg Pitch	Analysis (based on ant. pattn)

SSTI

TT&C SUBSYSTEM
STATUS/SCHEDULE SUMMARY

TRW

- TRANSPONDER (Will Meet All Requirements)
  - FINALIZED EQ SPEC (15 Jan 95)
  - LORAL CONIC TERRACOM UNDER LETTER CONTRACT; FULL CONTRACT ESTIMATED FOR 15 Jan 95
  - DELIVERY 15 DEC 95
  - UNDERBUDGET
- RF ASSEMBLY (Will Meet All Requirements)
  - SUBCONTRACT AWARD TO BE MADE NLT 15 Jan 95
  - DELIVERY ON 1 JUN 95
  - ON BUDGET
- ANTENNA (Will Meet All Requirements)
  - WATKINS JOHNSON UNDER CONTRACT
  - DELIVERY ON 1 APR 95
  - ON BUDGET

TT&C SUBSYSTEM
VERIFICATION APPROACH/ PLANS

- UNIT ACCEPTANCE TESTING WILL BE PERFORMED AND WITNESSED AT EACH VENDOR'S FACTORY
  - Performance
  - Thermal Cycling
  - Random Vibration
  - NO Thermal Vacuum (Will Be Performed at System Level)
    - Low Risk Units; Each Has Flight Hetritage
    - Reduces Cost/Shortens Schedule
- WILL CONDUCT ANTENNA PATTERN TESTING USING S/C MOCKUP AT SPACE PARK
- INTEGRATED SYSTEM TEST (IST) AND THERMAL VACUUM TEST WILL CHECKOUT THE ENTIRE S/C (Including TT&C Subsystem)
- COMPATIBILITY TEST WILL VERIFY INTEROPERABILITY WITH NASA GSTDN/DSN

SPACECRAFT BUS
Spacecraft Software

J. Stafa/B. Smith

SSTI

Flight Software Status

TRW

- Requirements in final review/update
- Preliminary design under way
- Internal software audit complete
  - Program and functional organization participation
  - Requirements, design approaches reviewed
  - Action items and conclusions approved by TRW spacecraft software skill center
- Three design alternatives identified
  - Trade studies complete
  - Spacecraft IPT will meet to review recommendations and select baseline approach
  - No new SSTI software has been produced, permitting design review, selection without software breakage

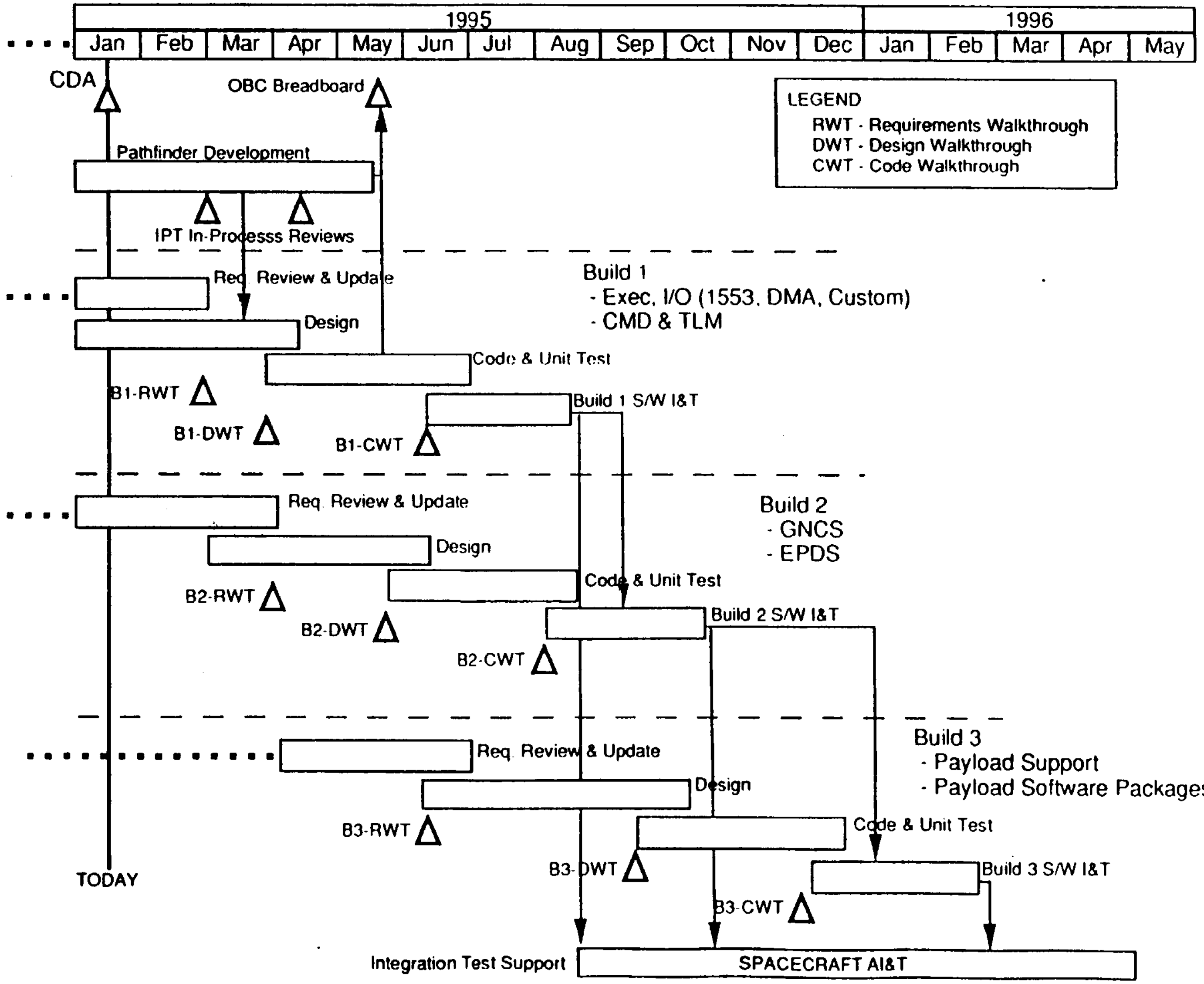
Schedule Driven Software Development

- Streamlined, tailored software process supports schedule to launch
  - Software integrated with spacecraft subsystems in end-item oriented development
  - Software is integral part of spacecraft IPT
  - IPT leads aggressive risk management for end-item success
- Concurrent Engineering facilitates development by integrated team
  - Requirements developed by software, subsystems, operations and systems engineering
  - In-place working reviews (walkthroughs) of S/W requirements, design and code implementation
  - Team ownership of end-item success

Incremental Software "Builds" Support Early Integration

- **Flight software built and delivered in 3 logically separate capability increments**
  - Overlapped development to support schedule
  - Each stage builds on previous product for integration "in-process"
  - Proven approach minimizes cost, risk
  - Meets Spacecraft I&T milestones
- **Pathfinder activities explores/resolves technical risks**
  - Feedback used to strengthen design
  - High confidence achieved before Build 1 is coded
  - Pathfinder code to run on SSTI OBC breadboard (May '95)

Flight Software Schedule



Software Design Alternatives

- Modify TOMS executive design (VxWorks OS)
  - All "C" implementation (limited to "C")
  - Port TOMS (80x6) executive for 32-bit R3000
  - No previous VxWorks/R3000 experience
  - MOCK Ada to be re-coded to run under VxWorks OS
- Reuse BP R3000 executive (DDC-I kernel)
  - Available "OTS" in Ada
  - Accommodates reuse in "C" (or other languages)
  - Supports other TOMS reuse (GNCS, EPDS)
  - Supports MIMO, Goddard compression "C" code
- Reuse BP executive with "all-Ada" software
  - Single language implementation
  - Lose existing TOMS "C" heritage software reuse

Second Option Recommended

- <u>Increases</u> SSTI software reuse
  - Adds BP executive reuse
  - Does not affect any other reuse
  - Microcosm has option to reuse Ada MOCK
- Fewer lines of code required on-board
  - BP executive is concise, provides all needed functions
  - Complexity, maintenance effort decreased
- Team has direct experience with BP exec
- "C" running under BP exec in two systems
  - BE end-to-end demonstration
  - BP star tracker
- Spacecraft IPT can assess each reuse component, select best approach

Requirements

- Draft Requirements document completed
- Finalization by each build
- Power and GN&C Appendices contain detailed logic and equations
- Modification from existing TOMS documents
- HW/SW ICD contains R3000 interface definitions
- Payload ICD contains 1553 protocol definitions
- Command and Telemetry Allocation Documents

Requirements Example

1.3 ATTITUDE COMMAND PROCESSING

The Attitude Command Processing subfunction receives commands from the command processing and scheduling subfunction. Only one command will be processed by this subfunction in any given major cycle. A command will consist of three parts. The first part is a handshaking flag that is zero if a new command is not present and unity if a command is present. This subfunction resets the flag to zero when a command is processed to acknowledge it and to make sure it doesn't process it again. The second part is a quaternion. The third part is ~~a flag~~ an integer that is zero if the quaternion is an orbit reference (LVLH) to body command ~~and~~ is unity if the quaternion is an inertial (ECI) to body command, and two if the quaternion is a UCB anti-sun command. ~~If a new~~ command is not present, this subfunction will continue to generate outputs based on the previous command.

This subfunction is called every intermediate cycle during Maneuver Mode and Science Mode. On one data base selected intermediate cycle in every major cycle, the command is processed. If it is an orbit reference to body quaternion, then an inertial to body quaternion command is calculated using the inertial to orbit reference quaternion from the ephemeris. If it is an inertial to body quaternion it is output to the destination unmodified. If a command is received on a different intermediate cycle, nothing is done with it until the correct intermediate cycle occurs again. This processing is done just after the ephemeris subfunction calculates the inertial to orbit reference quaternion, which also is only done once a major cycle.

On the other intermediate cycles, if the previous command was an orbit reference to body quaternion, then the output inertial to body quaternion is extrapolated for one intermediate cycle assuming that the orbit reference system has constant angular velocity. If the previous command was an inertial to body quaternion, nothing is done on the other intermediate cycles.

1.3.1 PROCESSING LOGIC AND EQUATIONS

b) Test for intermediate cycle on which commands ... first intermediate cycle).

IF intermediate cycle = 0 THEN

c) Test if command is inertial or o...

IF att_cmd_type = 0 ...

d) Convert com...
(swqcom...

can be considered to be equal to unity so that it doesn't need to be calculated. Also the sine of half the rotation angle is so small that it can be approximated by half the rotation angle. The data base constant ORB_RATE_DT > 0 equals the orbit rate times the intermediate cycle period.

```
del_q(1) = -(q_cmd(1)*q_cmd(2) + q_cmd(3)*q_cmd(4))*ORB_RATE_DT
del_q(2) = 0.5*(q_cmd(1)**2 - q_cmd(2)**2 + q_cmd(3)**2
        - q_cmd(4)**2)*ORB_RATE_DT
del_q(3) = (q_cmd(1)*q_cmd(4) - q_cmd(2)*q_cmd(3))*ORB_RATE_DT
```

END IF on command presence

ELSE ~~inertial-to-body-command-quaternion~~ IF att_cmd_type = 1 THEN inertial to body command quaternion

g) Test if new command is present.

IF new_att_cmd = 1 THEN

h) Send inertial to body quaternion command to output.

```
swqcom(1) = q_cmd(1)
swqcom(2) = q_cmd(2)
swqcom(3) = q_cmd(3)
swqcom(4) = q_cmd(4)
```

END IF on command presence

Add code from attached sheet

END IF on command type

i) Buffer the attitude command type so that a change of command type will not affect the extrapolation process before the processing in (d) to (h) is done.

1.3.2 INPUTS

Subfunction: Attitude Command Processing

Variable Name	Description (use, definition)	Units	Range/ Value	Type	Source
att_cmd_type	attitude command type flag	ND	0, 1, 2	integer ~~logical~~	SW Executive, 5.2 Mode Transition Logic
new_att_cmd	new command flag	ND	0, 1	logical	SW Executive
q_cmd	command quaternion (4-vector)	ND	-1 to 1	floating point	SW Executive, 4.1 CSSA Data Processing
swqEcO	ECI to orbit reference quaternion (4-vector)	ND	-1 to 1	floating point	1.8 Orbit Ephemeris Procesing
ORB_RATE_DT	pitch rotation angle over 1.024 sec	radians	1.0E-3 to 1.1E-03	floating point	Database
q_ucb	UCB anti-sun command quaternion (4 vector)	ND	-1 to 1	floating point	1.8 Orbit Ephemeris Processing

SSTI

Requirements Highlights

TRW

- Initialize from EEPROM, CODA
- Support 2K command uplink
- Provide realtime and stored commands
- Allow modification of both code and database
- Provide 8K bps SOH and 2.048M bps SSR readout downlink
- Control payload devices using the 1553 bus
- Broadcast time over the 1553 bus to 1 millisecond accuracy
- Control science and SOH data flow to the SSR

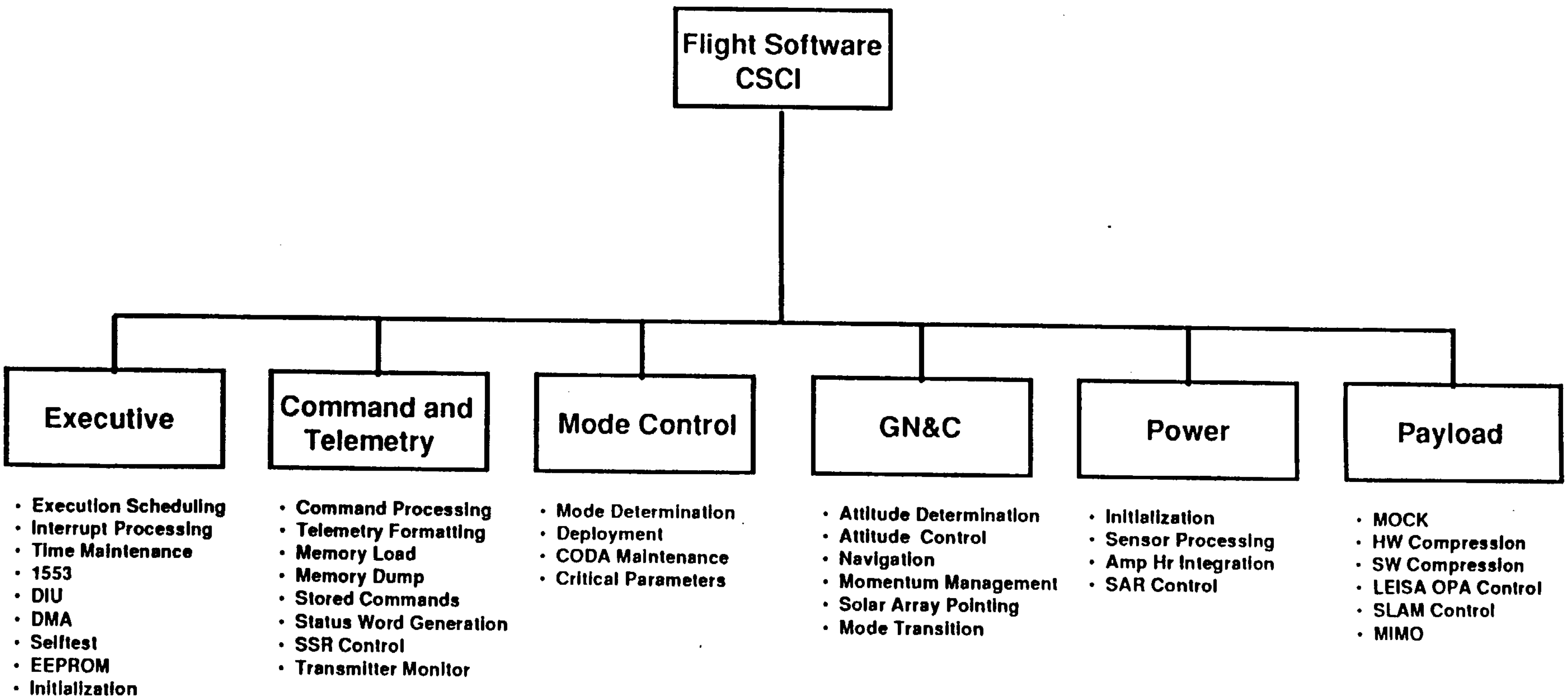
Requirements Highlights (Continued)

- Provide fault detection and safing logic
- Support HW and SW image data compression
- Provide attitude determination
- Provide attitude control
- Provide navigation estimates
- Point the solar array
- Provide delta V control
- Provide battery charge control

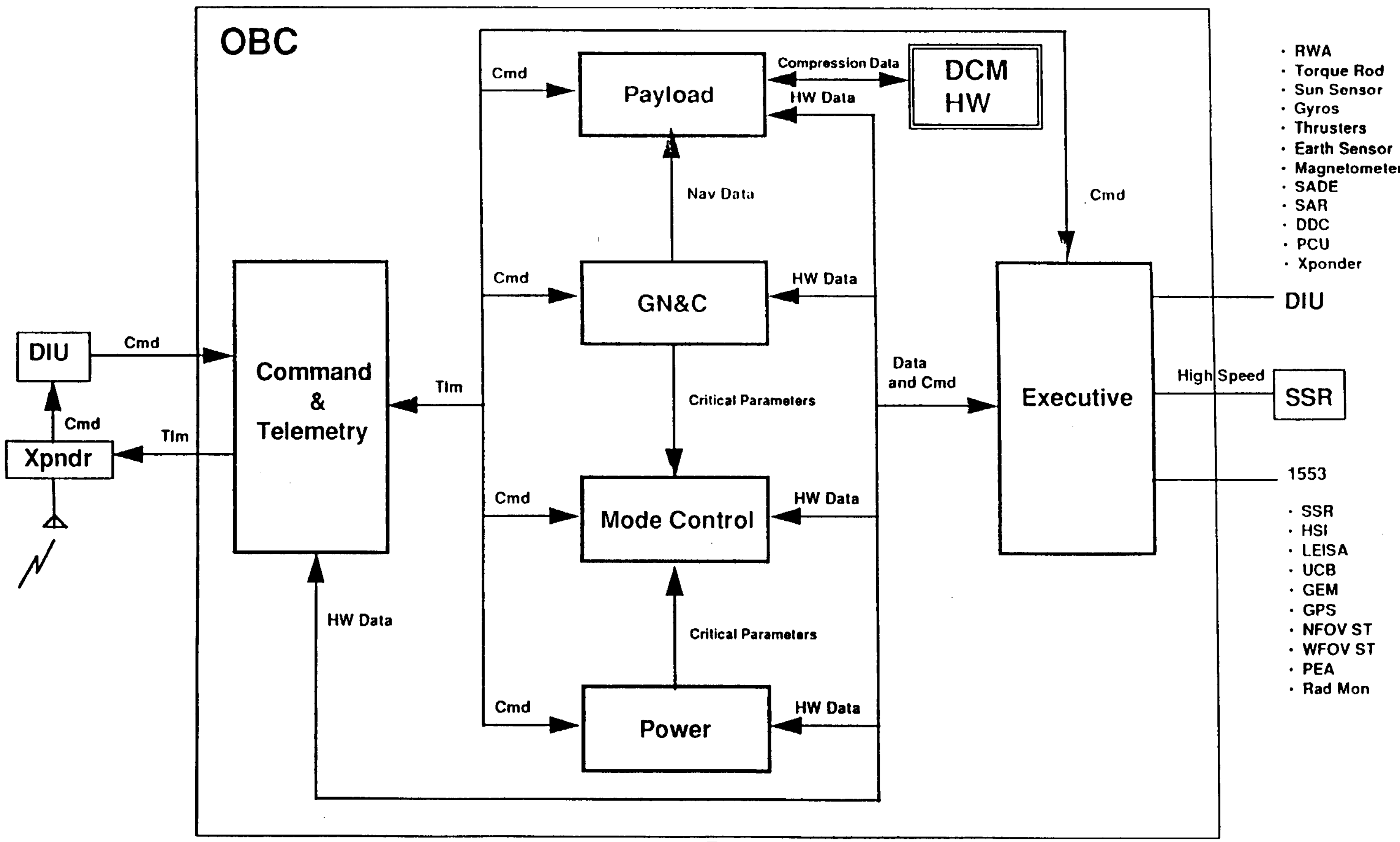
Requirements Highlights (Concluded)

- Provide OPA Mirror control
- Perform the MOCK software experiment
- Perform the MIMO software experiment

CSCI Structure



Software Architecture



SSTI

Preliminary Size & Throughput

	SLOC	Reuse	Source
Executive	2500	Moderate*	New, BP/BE
Command & Telemetry	1500	Moderate	New, BP/BE
Mode Control	400	Moderate	New,TOMS
GN&C	3200	Moderate+	New,TOMS, AB
Power	1000	High	TOMS
Payload	TBS	Small	New

* Scheduling high, I/O new

- **HW capacity 8 MIPS**
- **Typical spacecraft bus function less than 1 MIP**
- **2 Mbit telemetry estimated at about 1 MIP**
- **Payload compression not time critical**
- **MOCK is only time critical payload function**
- **Complete throughput estimate needed by Spacecraft IPT**

CLOSURE
Program Milestone Summary

L. Lane

Program Milestone Summary

- Schedule update will be completed this month
- Schedule changes are primarily in de-coupling tasks and changing serial activities to parallel activities wherever possible

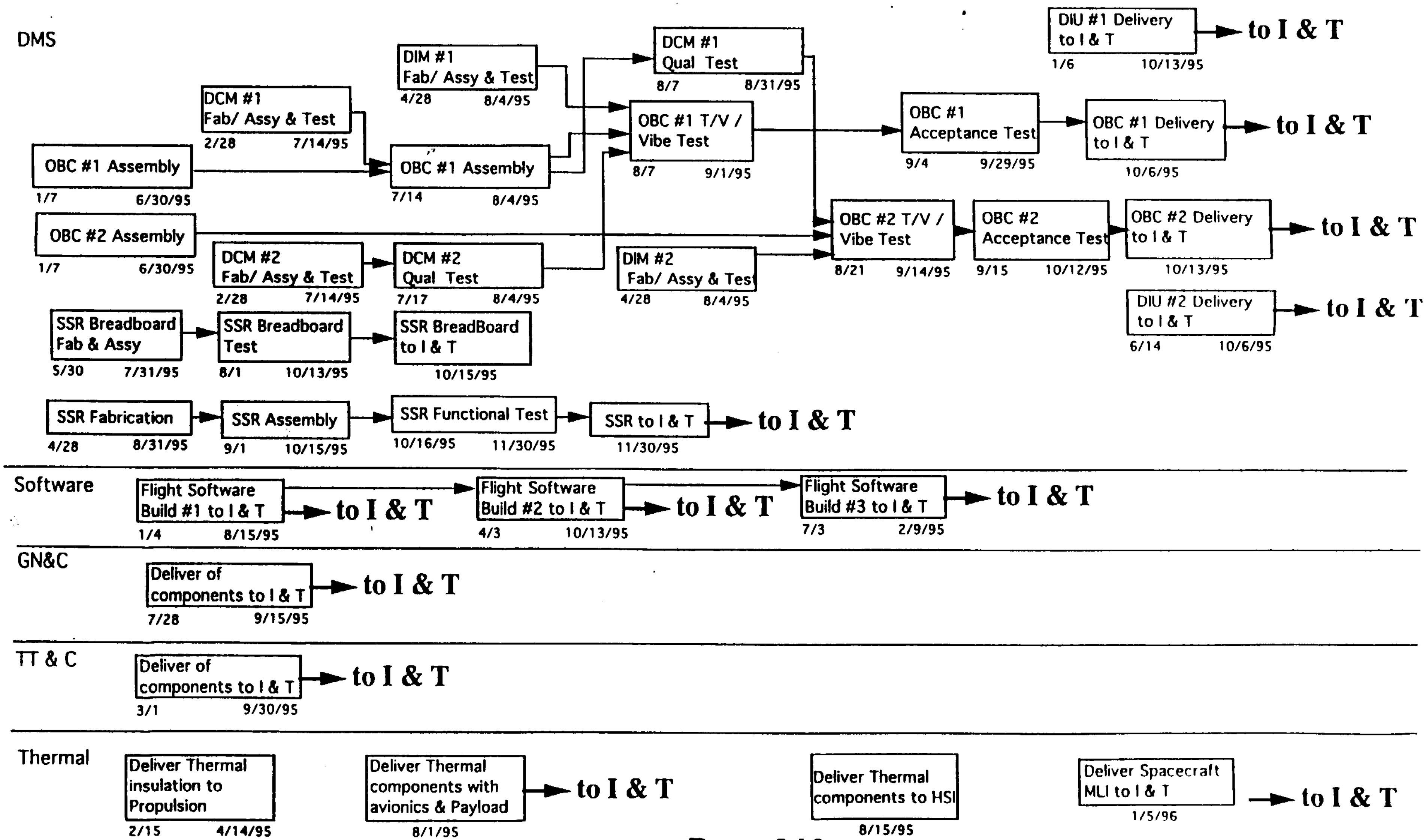
SSTI

Program Milestone Summary

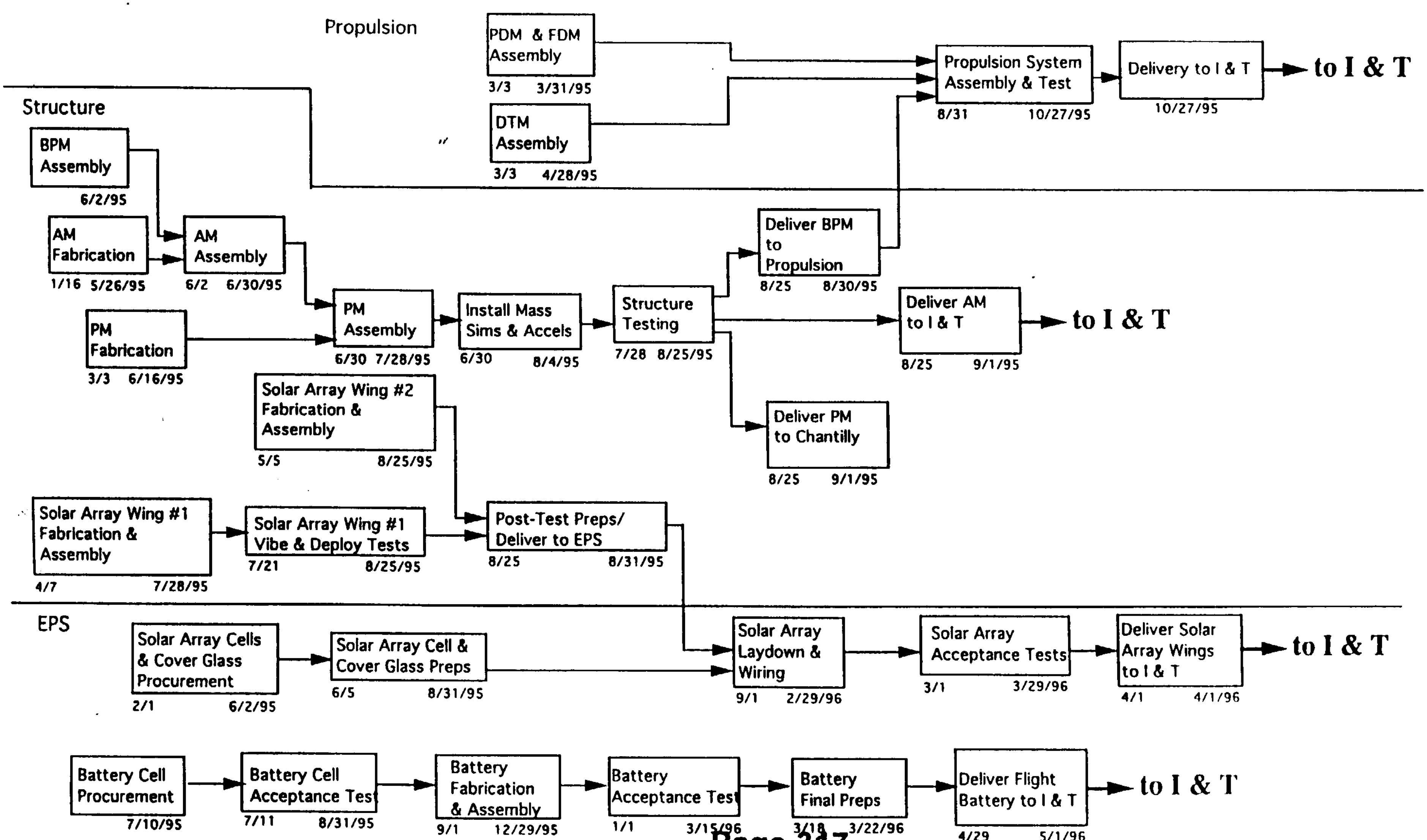
TRW

1995	Jan	-	Start Structure Fabrication
	Feb	-	Start Solar Array Cell Procurement
	Mar	-	Spacecraft Test Computer Checkout Completed
	Apr	-	Start EGSE Test Software Development
	May	-	Battery Propulsion Module Completed
	June	-	EGSE Integration Completed
	July	-	Structure Completed
	Aug	-	Flight Software Build #2 Completed
	Sept	-	Structure Testing Completed
	Oct	-	Flight Units and Structure delivered to I & T
	Nov	-	Flight Solid State Recorder delivered to I & T
	Dec	-	Flight HSI delivered to I & T
1996	Jan	-	Thermal Cycle Tests Completed
	Feb	-	Thermal Vacuum Tests Completed
	Mar	-	Spacecraft IST Completed
	Apr	-	Solar Array Release & First Motion Tests Completed
	May	-	Final Spacecraft IST Completed
	June	-	Shipping to Launch Site Completed
	July	-	Launch

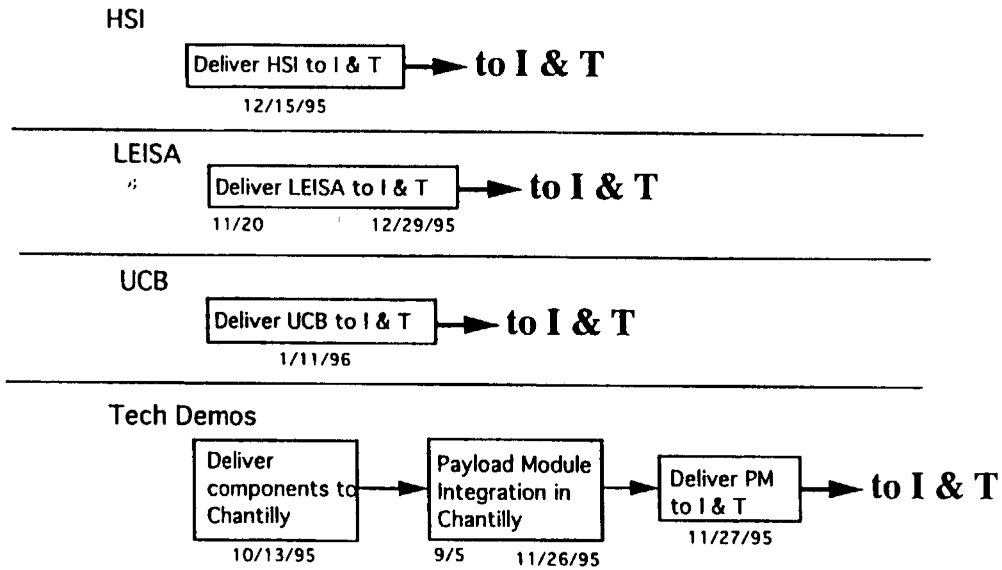
Network Schedule
Avionics



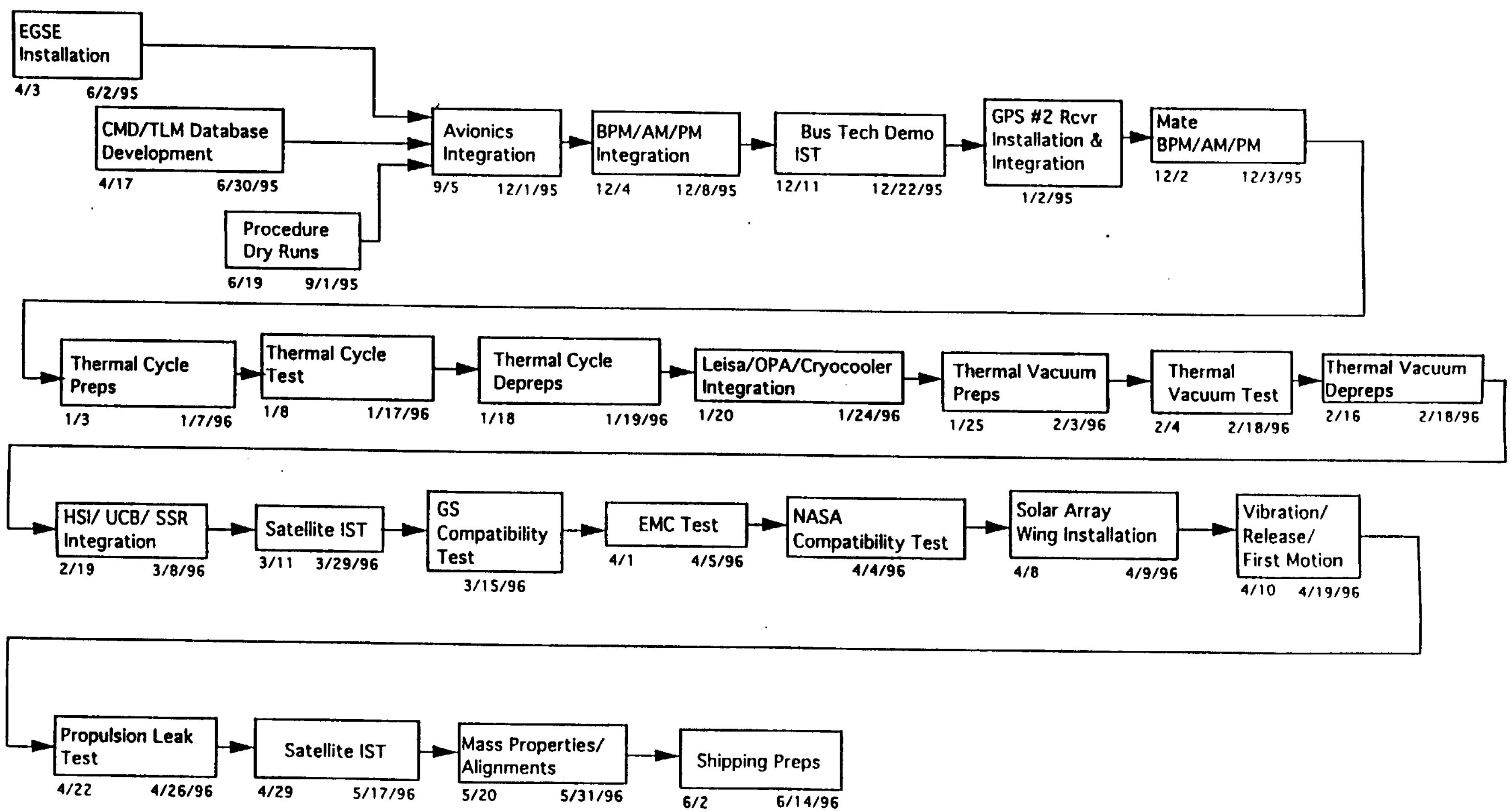
Network Schedule
Structure/ Propulsion/ EPS



Network Schedule
Payloads & Tech Demos



Network Schedule Integration & Test



CLOSURE

Closing Remarks

M. Watkins/T. Sabelhaus